The AMSAT® Journal

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Perhaps the most impressive photograph to come out of the Amateur Radio satellite program is the above photograph of a crescent Earth taken by the AO-40 SCOPE camera on 07AUG01. Similar to Apollo 8's famous *Earth-rise Over the Moon* photograph. the above photograph serves as an inspiration for all Amateur Radio satellite enthusiasts.

Moving Toward our Next Satellite Project

Since the AMSAT-NA Board of Directors' (BoD) February 2001 meeting in Orlando, Florida, much has been happening with planning and developing the next AMSAT-NA satellite project. At that BoD meeting, two similar satellite proposals were presented and discussed. Both satellites being considered are proposed for a geo-stationary transfer orbit and would carry a similar Amateur Radio package.In addition, Phil Karn, KA9Q proposed flying an efficient and innovative digital modulation mode for multi-user voice and data via a high rate QPSK modulation and Time Multiple Domain Access (TMDA).

[continued on page 4]

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Apogee View

On page 1 of this issue of *The AMSAT Journal*, begins a full description of two very important AMSAT-NA meetings that took place during the summer of 2001.

These meetings were of the Project Committee and the Business Development Committee, and maybe I should provide for you a little of the background which resulted in the formation of these two committees. While Keith Baker, KB1SF was your President, many discussions took place on the future of AMSAT and several suggestions were made, by the membership, on future satellite projects.

Acknowledging that our Board of Directors (BoD) were not directly involved in the design and building of satellites, it was decided that a committee should be formed to advise the BoD on the various projects which were being recommended by the members. This committee, which comprises a majority of the known designers and builders, soon became the AMSAT-NA Project Committee, who oversee the design, building, testing etc. of AMSAT-NA projects. If you have skills in these technical areas and would like to join the Project Committee please let me know.

The BoD decided that, as it has been some time since a project was managed by AMSAT-NA, that they would ask the Project Committee to manage the new project. Similarly it was decided that a Business Development Committee should be formed to support the activities of the Project Committee. This committee is responsible for publicizing the project and arranging the financing of the project, within the tax guidelines [501 (c) (3)] and requirements of AMSAT-NA .

The formation of these committees is essential to the operation of AMSAT-NA since we have grown to be an organization of over 5000 members and require an internal operation that will match the services required by the membership. Gone are the days when a *President's Letter* to the membership would raise enough funds to design, build and launch a satellite. A more sophisticated business approach is required.

This is why you will once more be asked to participate in fund raising. Current estimates of cost amount to approximately $200 per member per year and this will continue for as long as we want to keep building and launching satellites. This may seem like a large amount, however compared to most other recreational activities, the cost is small especially if you consider annual dues to the golf club, sailing, etc, etc. An easy way of participating is to be a donor to the Presidents Club. For a monthly donation you can become President's Club donor that has various advantages. (see the advertisement on page 2).

At Atlanta I look forward to meeting the President's Club Donors at a reception on Friday evening. Will you be invited to be there as a Donor?

73,

Robin Haighton VE3FRH

President AMSAT-NA ■

Results of AMSAT Board of Directors Election

As a result of the election, WD4ASW, W4PUJ, VE3FRH and W3XO will retain their seats on the Board for two years. KK5DO is the First Alternate and W2GPS is the Second Alternate. They will serve until the next election. The results of the election are:

Bill Tynan W3XO	871
Robin Haighton VE3FRH	824
Richard Daniels W4PUJ	760
Barry Baines WD4ASW	704
Bruce Paige, KK5DO	494
Richard Hambly W2GPS	447

[Continued from page 1] It was also suggested at this meeting to employ a KISS concept when constructing our next satellite projectand to have the project completed within three years.* After considerable discussion and analysis, the BoD felt that both satellite projects held suitable merit but both proposed projects required additional technical evaluation before a final decision could be made. (For complete details of this meeting, see "Report of the AMSAT Board of Director's Meeting," *The AMSAT Journal*, July/August 2001.)

** Editor's Note: AMSAT-NA's next satellite project has already been coined* ***Project JJ****; named after Dick Jansson, WD4FAB and Lyle Johnson, KK7P who each developed preliminary design proposals. However, like most modest satellite designers, Jansson and Johnson seek another name for this satellite. In this article, Project JJ is referred to as "the next satellite project." Stay tuned for additional satellite name details forthcoming via the AMSAT-NA Atlanta symposium!*

Also at the Orlando BoD meeting, AMSAT-NA VP for Development Shep Sheppard, AA7MH presented an approach to obtain the necessary funding to construct and launch future satellite. The BoD realized that the next satellite project would require a concerted and coordinated effort to raise the necessary funds to finance such an endeavor. As a result, the BoD also suggested that both Project and Business Development committees meet separately to perform additional analysis for developing preliminary plans for the next AMSAT-NA satellite project. This article summarizes the results of these two meetings but more importantly, this article defines where *you* and other AMSAT-NA members can provide much need assistance and support in designing, constructing, and operating our next satellite. The most common thread to emerge from these meetings was the challenge to obtain the continuing support (technical, morale, and financial) from all AMSAT-NA members. Without your continued and increased support, AMSAT-NA cannot accomplish our next satellite project.

Project Committee: The Denver Workshop

The members of the AMSAT-NA Project Committee met in Denver, Colorado on 14-15 July 2001 to define AMSAT-NA's next satellite project (Figure 1). Over the course of the workshop, detailed presentations were made on the two proposed satellite projects and the associated challenges that must be met to address various physical and design issues. These presentations were informative, complex, and diverse and afterwards came the hard part of the workshop; discussing and defining the who, what, where, why, and when's of the next satellite project. As a result of these detailed discussions, the initial design was confirmed of placing the satellite in a highly elliptical geo-stationary transfer orbit similar to that of AO-40. Meanwhile, Robin Haighton, VE3FRH, with the assistance of Jan King, W3GEY and Tomas Svitek were asked to explore options for obtaining a launch that can meet these orbital parameters. Once the orbital characteristics of this satellite were clearly defined, the committee was able to identify the following components that would be included on the next satellite:

- Linear (SSB/CW) uplinks on 70 and 23cm bands with a 13cm band down link;
- Digital voice communications (TDMA) 23cm band uplink with 13cm band downlink;
- 2 meter band omni-telemetry beacon;
- Gain antennas for 70, 23, 13cm bands;
- Omni-directional antennas (for initial commands and in the lower part of the orbit);
- Propulsion system (Only included if

Figure 1. Members of the AMSAT-NA Project Committee in attendance at a workshop in Denver, Colorado. From left to right (with area of expertise in parentheses): Russ Tillman, K5NRK (Technology Transfer); Jim White, WD0E (Systems Engineer, Software Design, and Command Station); Chuck Green, N0ADI (Design and Integration & Workshop Moderator); Lou McFadin, W5DID (Design and Integration); Stan Wood, WA4NFY (Design, Integration, and Antennas); Ed Collins, N8NUY (Special Assistant to the President); Michael Kingery, KE4AZN (Mechanical Design); Dan Schultz, N8FGV (Operations); Paul Williamson, KB5MU (Software Systems and Electronic Publications): Lyle Johnson, KK7P (Spacecraft Flight Computer Design); Tomas Svitek (Guest by invitation of Jan King); Bdale Garbee, KB0G (Software and Digital Design); Rick Hamby, W2GPS (Digital Software Data Communications); Dick Jansson, WD4FAB (Mechanical and Thermal Design); John Conner, NJ0C (Ground Support); Phil Karn, KA9Q (Internet Protocol); Robin Haighton, VE3FRH (President & Board of Directors); Brian Straup, N5YC (Ground Station); Mark Kanawati, N4TPY (Satellite Design and Integration); Arthur Feller, W4ART (Treasurer). (Photo by Mark Kanawati, N4TPY)

absolutely necessary, as this is a function of yet undetermined launch orbit. Inasmuch, the satellite may require some form of simple system for perigee adjustment. A decision on whether a propulsion system is required will be made in the near future when further launch guidance is obtained.)

Design and Construction: An overall decision was made at the workshop to proceed with a spacecraft design consisting of module sizes (volume and mass), electrical connectors and interfaces, module identification, preliminary power budget and performance specifications for each identified module (Figure 2). Each module will be developed and tested at a separate location and then integrated with the satellite at a central location. Furthermore, in advance of construction, all modules will require a development and test plan to ensure timely delivery for satellite integration. A goal was set to conduct a preliminary design review by the end of 2001 followed by a critical design review a few months later. Lyle Johnson, KK7P and Chuck Green, N0ADI agreed to co-manage the project through the critical design review stage. In summary, tentative key development milestones are:

- December 2001: Preliminary Design Review & Identify Potential Launch Opportunity
- February 2002 (est.): Critical Design Review
- February-December 2002: Build and Test Modules
- January-December 2003: Integrate and Test Modules on Satellite
- January 2004: Available for Launch Campaign

To accomplish this effort, the following assignments (in alphabetical order) were made:

- Antennas: Stan Wood, WA4NFY
- Cameras – Lens: Lou McFadin, W5DID
- Cameras – Detector: Lyle Johnson, KK7P
- Command Team Leader: Stacey Mills, W4SM
- Chief Information Officer: (currently unassigned)
- Computers & Related Sensors: Lyle Johnson, KK7P

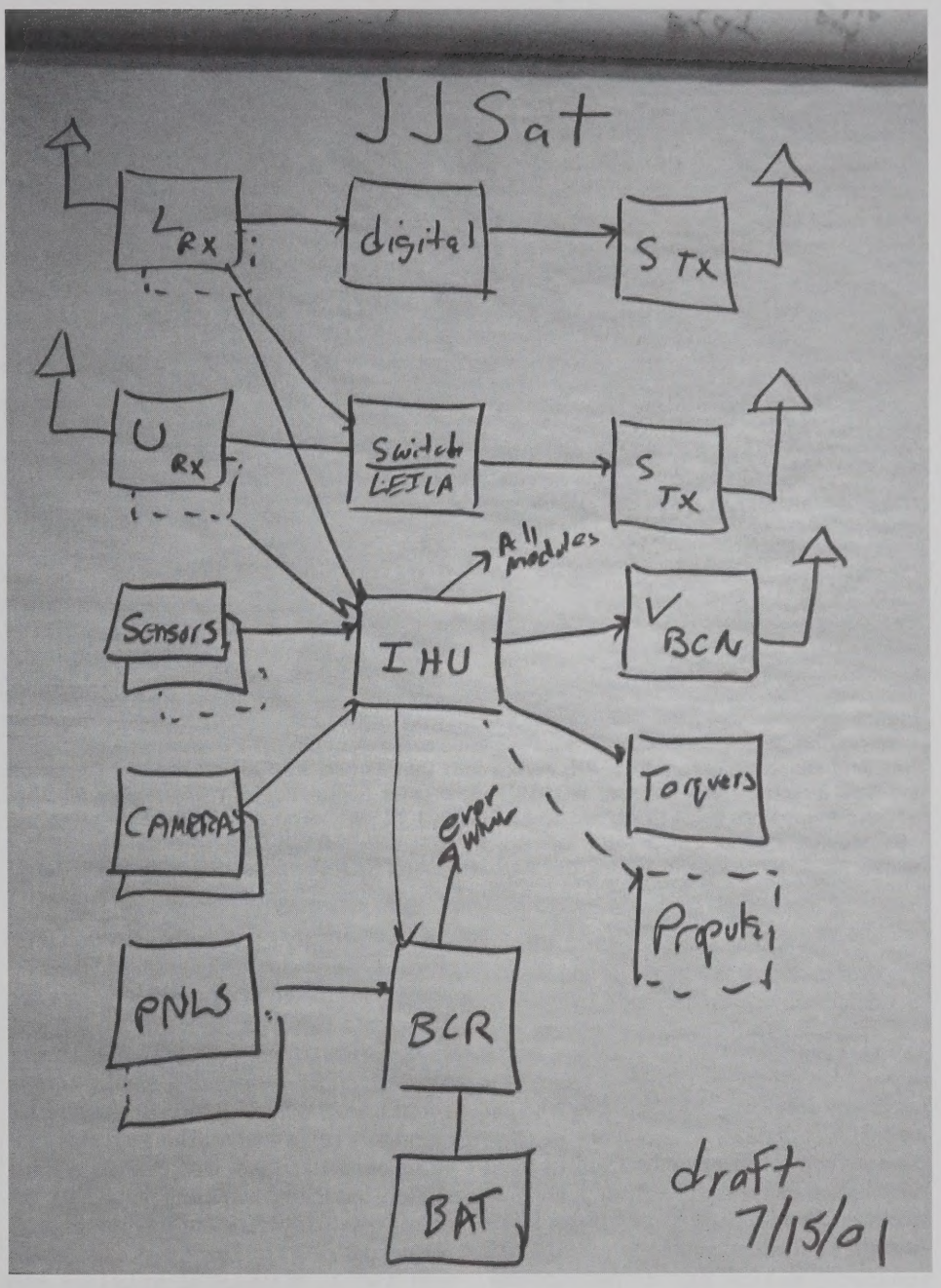

Figure 2: In the tradition of designing the next satellite on the back of a cocktail napkin, workshop members used an easel scratchpad to identify the next satellite's components and their associated relationship. (Photo by Mark Kanawati, N4TPY)

- Digital Communications: Phil Karn, KA9Q
- Digital Ground Hardware: Brian Straup, N5YC
- Launch Availability: Robin Haighton, VE3FRH; Jan King, W3GEY; and Tomas Svitek
- Magnetorquors: Lou McFadin, W5DID
- Mechanical (launch dependent decisions): Dick Jansson, WD4FAB: Lyle Johnson, KK7P; Stan Wood, WA4FNY; and Chuck Green, N0ADI
- Mechanical Design: Dick Jansson, WD4FAB and Mike Kingery, KE4AZN
- Navigation Sensors: Lou McFadin, W5DID
- Power System: John Conner, NJ0C Propulsion (launch-dependent): Tomas Svitek
- Regulatory: Dick Daniels, W4PUJ
- Thermal Design: Dick Jansson, WD4FAB

Figure 3: Members of the AMSAT-NA Business Development Committee meeting at a workshop at AMSAT-NA headquarters, Silver Spring, Maryland. From left to right: President Robin Haighton, VE3FRH; ANS Editor Dan James, NN0DJ; VP of Field Operation and BoD Member Barry Baines, WD4ASW; Treasurer Arthur Feller, W4ART; BoD Member and Immediate Past President Keith Baker, KB1SF; Corporate Secretary Martha Saragovitz; Journal Editor Russ Tillman, K5NRK; Mal Preston, NP2L; VP for Education Steve Bible, N7HPR; and VP for Development Shep Sheppard, AA7MH. (Photo by Perry Klein, W3PK)

- Project Co-Managers (Until critical design review is completed and launch details have been decided): Lyle Johnson, KK7P and Chuck Green, N0ADI

Other key results of the Denver Workshop include a commitment to employ an *open concept* for providing members with detailed information on the development of the next satellite. That is, every aspect of this satellite will be made available to the AMSAT community as a call for their participation. In addition, the need to develop and train new command and control stations in advance of the launch of the next satellite was urged in writing by Stacey Mills, W4SM. Mills suggested establishing an apprentice command and control station program that would ensure a continual supply of well-trained and equipped stations that would be ready by launch. Further details on these issues will soon be made available for member's participation.

Business Development: The Silver Spring Workshop

Members of the AMSAT-NA BoD have recognized that the internal and external environment in which AMSAT-NA constructs and launches its Amateur Radio satellites has radically changed. In the past, satellites were relatively simple in design and were literally constructed in members' garages and basements. However, AMSAT-NA has progressed to more complex missions and multi-team technical designs that require careful coordination and integration in a controlled laboratory environment. This increases construction costs. Also, launch costs are rising too, due to the increasing number of secondary payloads being built. Given this dynamic and new environment, costs for the next AMSAT-NA satellite project are estimated at approximately:

Construction:	$600,000
Testing & Launch Campaign:	$400,000
Launch Fees:	$2,000,000
Total Cost:	$3,000,000

Certainly a few comments are in order regarding this *estimated $3M price tag*. A significant portion of these expenses are ($2M) to for a launch fee. Presently, an exact cost for launching the next satellite is being determined and as a launch source becomes better defined this cost will become more exact. However for the time being, a $2M cost is a conservative planning estimate. As mentioned earlier, designing, constructing, and testing the next satellite will take about three years. That is, the satellite should be ready for a launch campaign by January 2004. Therefore, this will require AMSAT-NA to raise $3M for the three-year endeavor, or roughly $1M per year. AMSAT-NA's ability to raise funds will be significantly tested and it will be a challenge to involve every member in the project. Furthermore, during AMSAT-NA's next satellite project, there will be more for members to do than just donate funds or observe the process. Members' help is needed with the construction, testing, and launch campaign phases. Command and control stations need to be established. Members will be needed to market the project to external funding sources as well as traditional sources such as hamfests and club donations.

To better position itself to meet the above mentioned challenges, the AMSAT-NA BoD established a Business Development Committee (Figure 3) and assigned them the task of ensuring that the AMSAT-NA organizational structure and the way it does business is correctly aligned to meet its existing and future projects. Included in this charge was to capitalize membership's involvement in its projects and associated fundraising. Complimenting the successful results of the Denver Workshop, the AMSAT-NA Business Development Committee met on 17-18 August 2001 at AMSAT-NA headquarters to forge a start on the BoD's charge. One of the first tasks for the committee was the difficult task of defining AMSAT-NA business development:

With BoD guidance, the Business Development Committee uses a variety of internal and external resources to develop and implement business and financial activities to ensure AMSAT-NA's continued viability to successfully execute its projects.

Next the members attempted to identify and sort out short- and long-term objectives that would allow AMSAT-NA to have the capability to conduct its various projects (the next satellite project, ARISS, assistance with MOST, etc.). Of primary discussion was how AMSAT-NA could raise the necessary funding to cover the $3M construction and launch expenses the next satellite project. To assist the committee, Ms. Jill Barken, a fundraiser for Columbia University informed participants on various internal and external fundraising strategies. A key message of Ms. Barken's presentation was the need to develop long-term relationships with potential donors (i.e. it doesn't happen overnight!). She also informed participants that the best source of funding was members, who have a vested interest in the project. As a result of

Ms. Barken's presentation, the committee identified the long-term objectives of obtaining external (corporations, foundations, government and individuals) funding sources as well as empowering a variety of internal sources for a constant source of donations. It was also recognized that this effort will continue to be a challenge for AMSAT-NA to successfully master.

In addition to the above long-term objective, the following short-term tasks were identified:

- Prepare an AMSAT-NA Business Development Plan with Emphasis on Specific Project Plans and Communicate the Plan to AMSAT-NA Membership
- Have the AMSAT-NA Board of Directors Endorse and Adopt the AMSAT-NA Strategic Plan
- Write and Distribute a White Paper on AMSAT-NA's Changing Environment within which AMSAT-NA Must Operate
- Develop a WWW Site Devoted to AMSAT-NA Business Development
- Identify and Document AMSAT-NA's Technical Contributions Over the Years
- Develop and Enhance the President's Club Using a Variety of Sources and Ideas
- Develop and Implement Inventory Skills Survey
- Implement a Satellite Builder/Command and Control Certification Program

The Real Challenge: What Can I Do?

Lots of good things came out of the Denver Workshop. The next AMSAT-NA satellite has a proposed design and direction. In addition, preliminary timelines for construction and testing the satellite have been identified along with assignments for responsibility of developing a variety of satellite modules. An innovative and Internet-type digital voice operating mode using simple hardware on the spacecraft has been proposed that will allow more hams to access the satellite via low-cost satellite ground stations. All of these concepts will be emerging and communicated to members as designs are developed and tested.

Lots of challenges also came out of the Denver Workshop. With this ambitious project comes a hefty price tag; it will be a challenge for AMSAT-NA to raise the necessary funds. Also the need for new builders, ground station hardware designers, and command and control stations to come forward and help with this task was apparent. Inasmuch, there will be plenty of opportunities for interested members to work on this project. The open design concept will enhance members' awareness of ongoing developments. As a result, more opportunities will exist for locating and employing much-needed assistance during the development and testing of the satellite.

One of the key outcomes of the Business Development Committee workshop was that the entire business development concept is an emerging and new learning process not only for AMSAT-NA as an organization but a process for its members. Positioning AMSAT-NA to successfully accomplish its future projects, as well as obtain the funding necessary to accomplish those projects will be a continuing challenge that will test a variety of skills (including basic communication). While the answers to meeting this challenge are not yet all on the table, some key solutions are known. Those solutions lie in assembling and coordinating an effective AMSAT-NA membership to accomplish the task. Members who understand what the organization is attempting to accomplish and what their role is in the process. So make your commitment today to actively participate in our next AMSAT-NA satellite project!■

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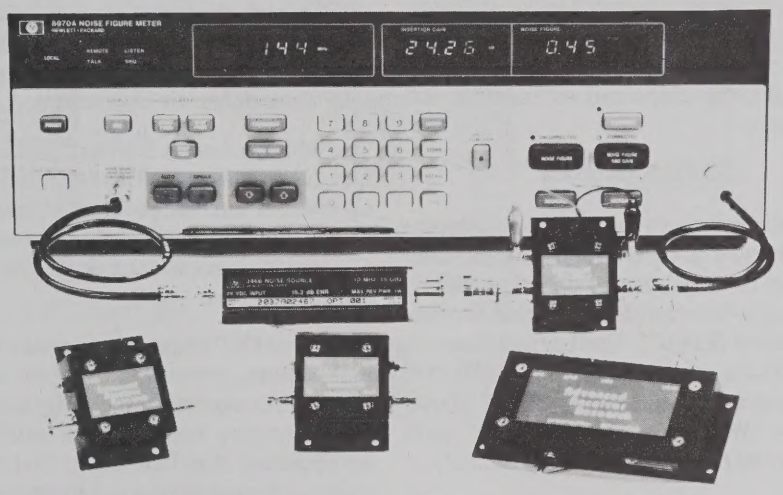

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P50VDG	50-54	<0.5	24	+12	GaAsFET	$79.95
P144VD	144-148	<1.5	15	0	DGFET	$29.95
P144VDA	144-148	<1.0	15	0	DGFET	$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	$79.95
P220VD	220-225	<1.8	15	0	DGFET	$29.95
P220VDA	220-225	<1.2	15	0	DGFET	$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	$79.95
P432VD	420-450	<1.8	15	-20	Bipolar	$32.95
P432VDA	420-450	<1.1	17	-20	Bipolar	$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	$79.95
Inline (rf switched)						
SP28VD	28-30	<1.2	15	0	DGFET	$59.95
SP50VD	50-54	<1.4	15	0	DGFET	$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	$109.95
SP144VD	144-148	<1.6	15	0	DGFET	$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	$109.95
SP220VD	220-225	<1.9	15	0	DGFET	$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	$109.95
SP432VD	420-450	<1.9	15	-20	Bipolar	$62.95
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RUDAK Digital Signal Processing on AO-40

Lyle Johnson, KK7P

The Regenerative Transponder for Digital Amateur Radio Communications (RUDAK) system now flying on AO-40 provides multiple channels of digital data capability. There are four fixed data-rate up- and downlinks at 9600 bps, using FSK. There are two fixed 153.6 kbps links using PSK. And there are eight links designed for slow to medium speeds using whatever modes and methods that may seem appropriate, based on digital signal processing (DSP). This article details the DSP facilities.

The purpose of this article is two-fold:

First, if you are interested in the technology used in RUDAK, this article will give you some detail about the DSP subsystem design.

Second, if you are interested in creating software to fly on RUDAK's DSPs, this article will give you the basic information you need to research the chips and architecture and write code.

RUDAK Overview

RUDAK consists of a pair of V53-based computers, known as CPU-A and CPU-B. Each CPU has 16 megabytes of directly addressable, single-bit error detecting and correcting memory (EDAC). Unlike the Microsats and UoSats, the so-called RAMDISK memory is part of this large array of EDAC memory. (Whether or not this was a good idea may be the topic of a future article!)

Each CPU has a pair of 9600 bps (9k6) FSK uplinks and downlinks. The uplinks are fixed on 2m (one per CPU) and on L-band. For now, the L-band uplinks are unpublished as these are being used for command and control of RUDAK. The 2m uplinks are not available when the U-band receiver is activated for general transponder use.

Each CPU also has a 153.6 kbps (153k6) PSK capability. CPU-A uses unshaped PSK. CPU-B uses shaped PSK, and also has an optional convolutional encoder on the downlink. Due to the bandwidth required, when a 153k6 downlink is activated, the 9k6 links must be turned off.

Each CPU has four (4) DSP-based uplink processors and four (4) DSP-based downlink processors.

The 153k6 and DSP uplinks are not fixed, but are routed through a selector controlled by the RUDAK CPUs. In this way, RUDAK can monitor the 400 bps telemetry from the IHU onboard AO-40, determine which receivers are active, and listen to the appropriate uplinks.

Serial Communications Interface

The interfaces between the CPU and the modems, whether fixed or DSP, are through dedicated serial communication controller (SCC) chips. RUDAK uses NEC uPD72001 integrated circuits (ICs) for this purpose. These are very similar to the Zilog SIO and 8530 series parts often used in packet radio TNCs. The 72001 has flown successfully in numerous AMSAT spacecraft, starting with the Microsats launched in January 1990.

Each SCC channel connected to the DSP modems area provides a transmit data (TXD) stream and corresponding transmit data clock (TXC), and expects a receive data (RXD) stream along with a receive data clock (RXC). A data carrier detect (DCD) output from a DSP demodulator is also accepted.

The DSP chosen for RUDAK is the Analog Devices ADSP-2171. This DSP chip contains 6k bytes of internal program memory (2k x 24), 4k bytes of internal data memory (2k x 16), bitwise input and output pins, timers and serial interfaces.

Like most DSP chips, this one has a Harvard architecture, separating program and data memory for maximum speed. By using separate memories, both program and data can be accessed simultaneously. External devices – whether memory or interface chips – use a common address and data bus, and are mapped to program or data space by decoding from the appropriate control signal from the DSP.

CPU to DSP Interface

DSP Modulator

As you have probably already discovered in life, entropy rules. Put another way, it is almost always easier to generate a signal than it is to detect one. The same applies to RUDAK – the modulator is simpler than the demodulator. So, we'll start by describing a DSP modulator.

The schematic diagram of a typical DSP modulator section has been provided for your reference. As you can see, it is very simple electrically.

The ADSP-2171 is clocked at 12.288 MHz (signal 13MHZ0 applied to CLKIN, pin 25). A single clock oscillator module drives the DSPs for CPU-A; an identical oscillator module supplies the clocks for all DSPs associated with CPU-B. This clock establishes the rate at which the DSP can execute instructions. In this case, it is just over 12 million instructions/second.

The TXC signal from the SCC (labeled M1TRXC3 on the schematic) is provided on nIRQ0 (the n prefix indicates the signal is asserted when LOW) pin 58 which can provide an interrupt to the DSP for each data bit. The data itself (TXD, labeled M1TXD3 on the schematic) is supplied on the flag input (FI) pin 60. This pin's state can be directly read, and a branch taken depending on its value, by software executing in the DSP chip.

After processing to create filtering, FSK or PSK, etc., the data must be translated to the AO-40 IF and passed to the IF matrix. The IF is nominally 11 MHz (Figure 1).

An Analog Devices AD7008 direct digital synthesizer (DDS) chip is employed to simplify this process. The DDS interfaces directly to the DSP's address and data bus and is controlled by the DSP's Data Memory Select (DMS) logic, thus mapping it into data memory space.

The DDS provides the ability to generate a signal with high precision in frequency (a 32-bit accumulator provides resolution less than 0.01 Hz in this application) and amplitude (internal 10-bit D/A). Because a DDS generates its frequency output by adding phase shift, it can be used to create PSK signals as well. Note that this particular IC provides I and Q channel *oscillators* internally, so that complex modulation may be created. It is possible, for example, to create an SSB signal with this part.

The AD7008 is clocked at 32 MHz by the signal labeled AD0CLK. It may be reset under program control by the FL0 output line from the DSP.

The output from the AD7008 is scaled and sent to a summing amplifier on the discrete modem board, where it is added to the other AD7008s associated with CPU-A or CPU-B, along with the 9k6 and 153k6 signals. The summed and buffered output is passed through a two section L/C network and sent to the IF matrix for downlinking.

DSP Demodulator

Each RUDAK CPU controls a 12-bit Analog-to-Digital Converter (ADC) which in turn

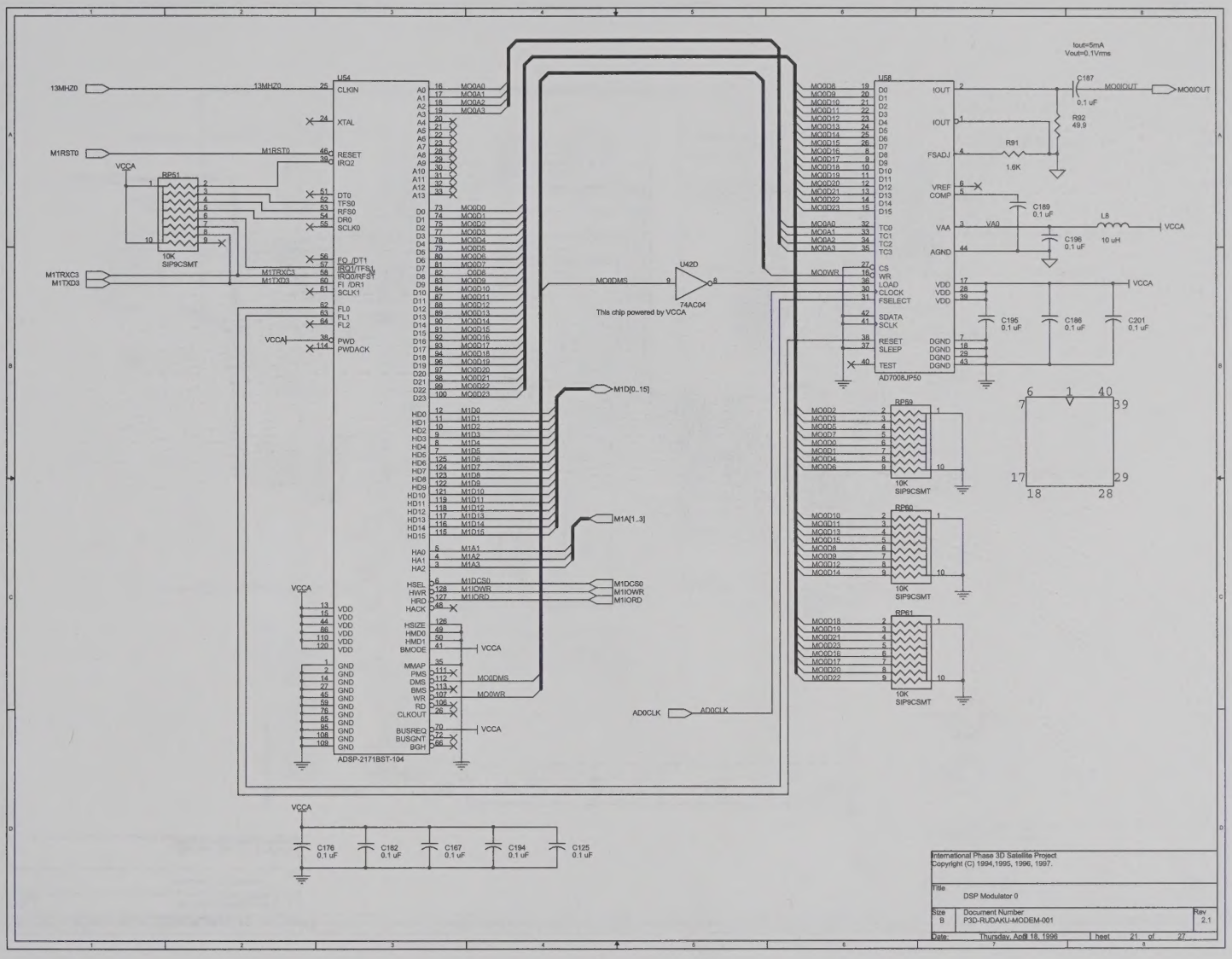


Figure 1. Phase 3D RUDAK Modulator

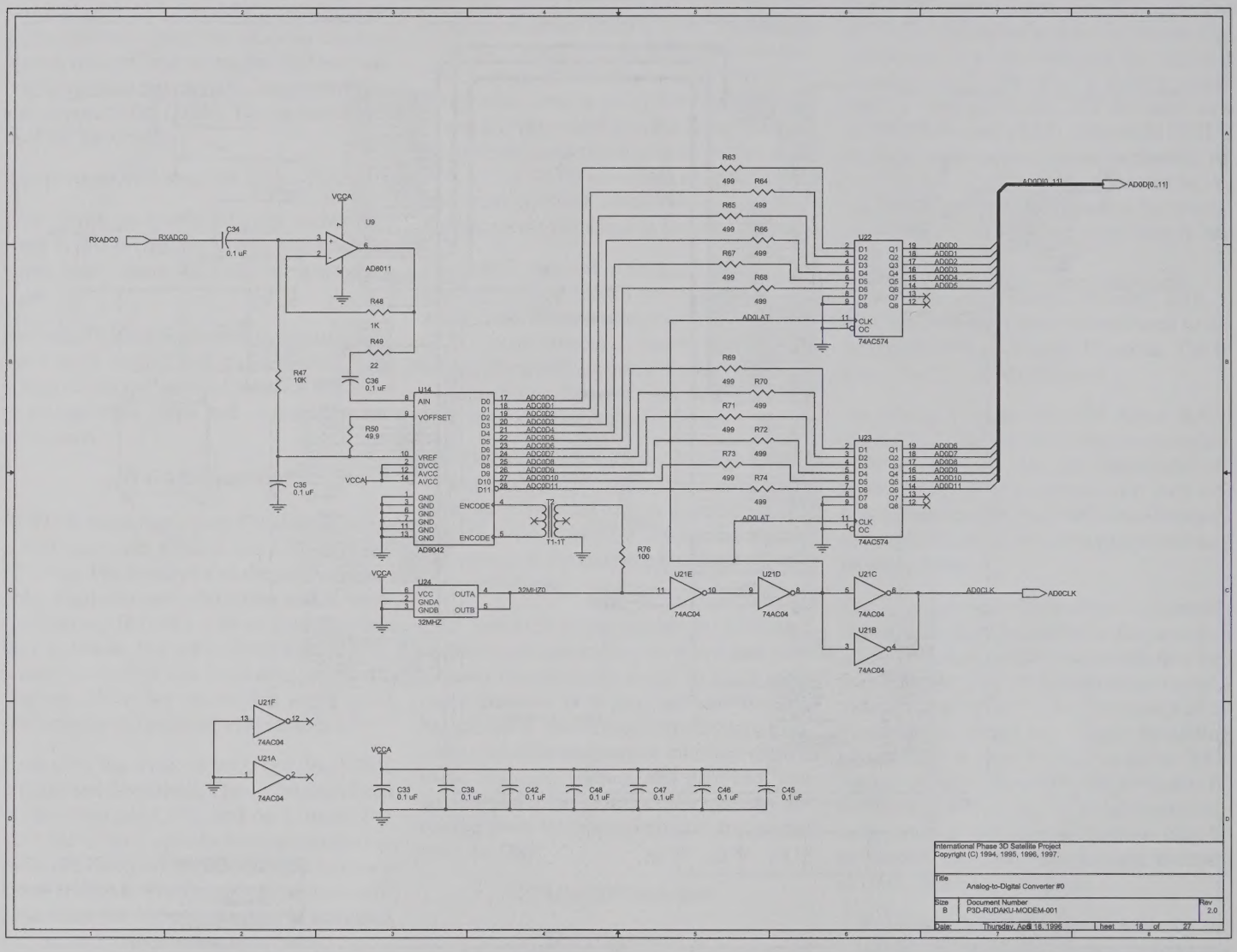


Figure 2. Phase 3D RUDAK Analog-to-Digital Converter

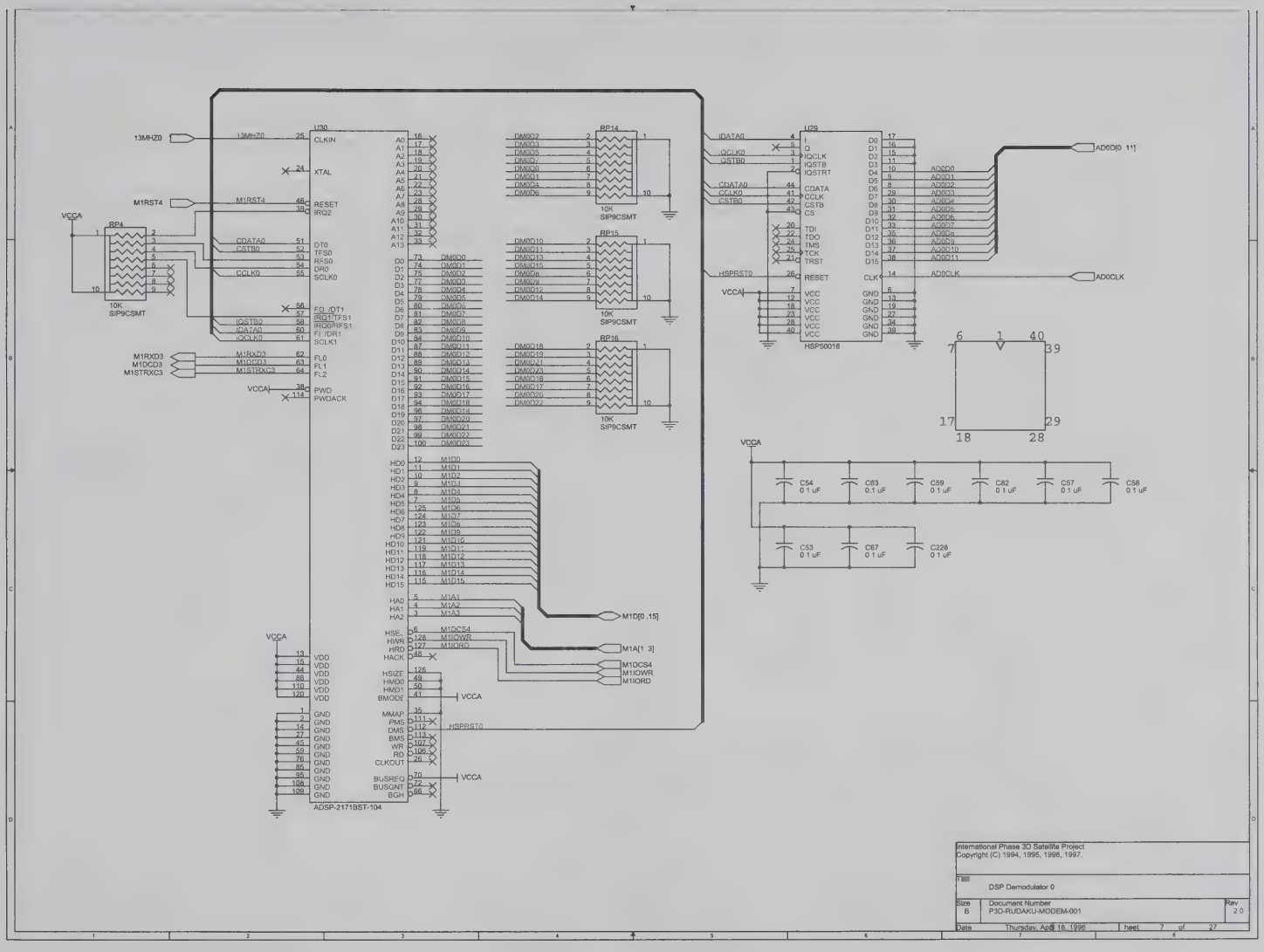


Figure 3. Phase 3D RUDAK DSP Demodulator

drives four (4) DSP demodulators.

ADC Front End

Incoming signals from the selected uplink IF (labeled RXADC0) are buffered by an AD8011 amplifier, DC offset and scaled for the ADC9042 ADC. The '9042 is a 12-bit converter and has a sample clock driven at 32 MHz. The 12-bit output is latched by a pair of 74AC574 octal D flip-flops and presented to four (4) DSP demodulators (Figure 2).

The 32 MHz clock is buffered and supplied to the DSP Modulators described previously as well as to the DSP Demodulators.

DSP Demodulator

Each demodulator consists of an Intersil (formerly Harris) HSP50016 Digital Downconverter (DDC) coupled to an ADSP-2171 (Figure 3).

The HSP50016 is a complex chip that provides an internal quadrature DDS local oscillator, a pair of mixers, a pair of matched 128-tap FIR filters and support circuitry. The result is a digital implementation of a receiver, complete with both I and Q channels. This means that image rejection is possible, resulting in less noise bandwidth for a given passband.

The HSP50016 accepts the 12-bit ADC data at a 32 MHz rate. After internal processing, the I and Q channel data are available serially to the DSP. The DSP contains a pair of internal synchronous serial ports that are employed for both commanding the DDC as well as accepting data from it for further processing.

After the demodulation process is complete, the DSP presents RXD (labeled M1RXD3) and RXC (labeled M1STRXC3) as well as DCD (labeled M1DCD3) to the RUDAK SCC. These signals are provided via FL0, FL1 and FL2 pins from the DSP.

DSP Development Tools

Analog Devices offers the Visual DSP tool set for Windows. See their WWW site for more information.

Unfortunately, the older version 5.1 DOS-based software, which I used for development and testing of the RUDAK DSP system, has apparently been removed from the Analog Devices FTP site. You may be able to locate the version 5.1 tools on the web someplace. I did find the following URL:

http://ux.aerospacesoftware.com/order.html

offers a CD-ROM at $20 which includes the 5.1 release as well as other DSP-related tools and information. I have not ordered this CD-ROM so I can't vouch for it.

Acknowledgement

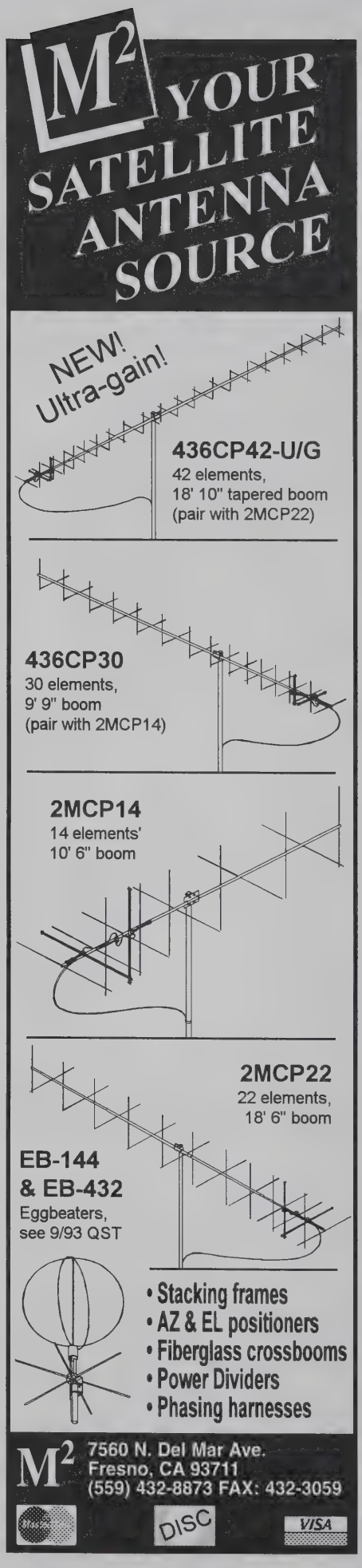
Analog Devices was very supportive of the RUDAK effort, including donation of the AD8011, ADSP-2171 and AD9042 ICs used in this project. They also supplied samples of the ADSP-2171 for radiation testing, and then provided ADSP-2171 chips for flight use made from the same process geometry.

For Further Information

Full data sheets on the ICs mentioned in this article are available at the following websites:

- Analog Devices *www.analog.com* AD7008, AD8011, AD9042, ADSP-2171
- Intersil *www.intersil.com* HSP50016
- Unfortunately, details on the NEC chips (V53 CPU and uPD72001 SCC) are not readily available on the WWW. I have details on the SCC that I can e-mail (these are large files totaling almost 2 megabytes) if you are *seriously* interested.
- In addition, *QEX* has run a series of articles by Peter Anderson, KC1HR, detailing use of the HSP50016 in an experimental *software radio* for HF work (AM, SSB and CW). I highly recommend you read these articles if you are interested in applying the HSP50016.
- *A Simple SSB Receiver Using a Digital Down Converter*, March, 1994, pp 17-23.
- *A Better A/D and Software for the DDC-Based Receiver*, November, 1994, pp 11-15.
- *A Simple CW Demodulator for the DDC-Based Receiver*, February, 1995, pp. 6-10.
- *A Simple CW Transmit VFO for the DDC-Based Receiver*, January, 1996, pp. 20-25 (describes the use of the AD7008).
- *A Better and Simpler A/D for the DDC-Based Receiver*, August, 1996, pp. 21-24.
- *A Simple Synchronous-AM Demodulator and Complete Schematic for the DDC-Based Receiver*, September, 1997, pp. 3-14.
- *A Faster and Better ADC for the DDC-Based Receiver*, September, 1998, pp.30-32.

I can be reached via e-mail at *kk7p@amsat.org*.■



2001 AMSAT Field Day Competition Results

Andy MacAllister, W5ACM

The 2001 AMSAT Field Day Competition was held in conjunction with ARRL's annual Field Day during the fourth weekend in June. Rules for the AMSAT activity were similar to those posted by the ARRL, but with a few key exceptions. While the ARRL rules lump all Amateur Radio satellite activity in one category, AMSAT rules differentiate activity via various hamsats as separate bands. The AMSAT rules also provide bonus multipliers for digital satellite downloads and uploads of Field Day greeting messages.

Every available Amateur Radio satellite had Field Day participants in pursuit of contacts. The AMSAT Field Day rules encourages foreign stations to join the event, and several DX stations were quite active both on the analog and digital satellites.

Totals were substantially lower this year, at least for the top scores. AO-10 was running reasonably well, but made a North American perigee pass only during the last part of the event. Due to its age, and the fact that the onboard computer has been offline for over a decade, it's always a delight to make any contacts at all during Field Day via AO-10. Doug Chauvin, N8PYN put it in perspective, "It was refreshing to see that AO-10 is still putting out a valuable service while AO-40 is maturing." Another factor that kept the points count down was the availability of only UO-22 for 9600-baud digital work.

All of the top-scoring stations provided excellent documentation this year. Several spreadsheets were submitted via e-mail. In fact, almost all Field Day submissions were via e-mail.

Many thanks to all who operated in this year's event. It was a great opportunity to show other Field Day participants how easy and exciting satellites can be. It was also a chance for some competition on the birds and an occasion to test hamsat radio gear and antennas in emergency conditions.

Per the AMSAT Field Day announcement, the first-place portable station using emergency power will receive a plaque at the AMSAT meeting in Atlanta, Georgia. Second and third-place entries will receive certificates. The first-place home station running emergency power (ARRL Class E) will also receive a certificate.

Problems? Yes. A major complaint last year revolved around the FM-voice, single-channel hamsats; AO-27 and UO- 14. UO-14 has spent the majority of its time in orbit as a 9600- baud store-and-forward resource outside the ham bands for the Volunteers in Technical Assistance (VITA). When the digital system failed, it was returned to ham operation as another FM repeater in the sky. It has been fantastic, but Field Day contacts were virtually impossible in 2000 due to its popularity. Only stations with luck, large antennas and plenty of power made consistent UO-14 contacts. The AMSAT Field Day rules for the 2001 event only allowed points for *one* contact via each FM-voice satellite. Users were encouraged to make their contact, and leave. This helped, but low-power stations still found it impossible to get through.

While most of the rules worked well for Field Day 2001, we had an unexpected surprise this year, Susan Helms on the International Space Station was on the air, operating Field Day! The only changes expected for the AMSAT Field Day 2002 rules will be to allow contacts with the ISS.

Tim Cunningham, N8DEU for K4BFT: We had a great time during Field Day this year. Our approach was to have fun and let anybody get in front of the radio and make a satellite contact. We even had folks dropping by to operate at 0200 hrs in the morning. As usual we had our share of noise problems, but they only affected operation on the 10M downlink. It must have been one of the generators. We had a record in tear down time after Field Day this year. It took less than 50 minutes to pack all the equipment inside and on top of my Jeep this year. I am not quite sure where all the help came from at the end of Field Day, but I was sure happy to get home earlier. Our help included John Stensby, N5DF; Greg Gross, KE4ROL; John Hilliard, K4JCH; George Duncan, K4TFJ; John Reynolds, N5AYD; Dick Christiansen, W1TV; Steve Bell, KD4TFN; and myself.

Jerry Brown, K5OE: I got a late start, having gone to San Antonio, but got back just in time for the two UO-22 passes on Saturday night. FO-20 and FO-29 were the best birds for me, but I now realize I should have paid more attention to AO-10. I only checked on it once, did not hear anything, and only checked back about 5 minutes before LOS. It sounds like I missed a lot of opportunities. This was the first time I worked FD with my home antennas. Running with a NiCad pack and solar charger on the rig and a UPS for PC and rotor worked well, but limited my power output to 25W. I missed two passes of RS-12 when my UPS died and I did not realize the rotor was not actually doing anything!

Still, it was my best score ever, so no regrets. I'm looking forward to AO-40 in 2002.

Jim Huhta, AA4MD: Battery-powered satel-

S104E5092 2001/07/16 03:02:36

A very popular Field Day participant was COL Susan Helms of the Second Expeditionary Crew operating N1ISS from Alpha. Note the ARRL Field Day pin on her right collar. (NASA photo)

lite trailer station had many problems this year. Listen for us from Florida hamfests this fall.

John Santillo, N2HMM for W2LV: It rained so my score counts! :-)

Dirk, ON1DLL for ON5LL: Operators included William Leijenaar, PE1RAH and Dirk, ON1DLL. We ran on two separate stations that made us able to work different satellites at the same time. Our self-made antennas, both bands on a single boom, can be dismantled and carried in a bag pack. All power came from batteries and recharge of PE1RAH's backpack battery was done by a flexible solar array. We were QRV on the following satellites: AO-10, UO-14, FO-20, UO-22, AO-27, FO-29 and RS12. In total 39 QSO's were made on all of these satellites (38 SSB and 1 CW). One message was sent to UO-22 and 16 Field Day greetings messages *To All* were received from UO-22 from different stations. (We didn't count stations who sent three greetings messages.) Our Field Day station was a tent in an open field in JO21TD-Bree. Station 1 consisted of a FT290/790 with homemade handheld 4el-2m/7el-70cm single boom used with a FRG100 HF receiver and a dipole antenna for 10M. This station will be taken on our satellite DXpedition trough Europe (See *http://www.qsl.net/pe1rah* or via message on UO-22 for more information.) Station 2 consisted of an IC821H with a homemade handheld 4el-2m/8el-cm single boom Yagi with a TNC2H 9600 baud modem and a 386 laptop running WISP16 and IT.

Phil Berkowitz, KA1YIQ checks out AO-10 on Sunday morning while a visitor listens in at N1EV in Connecticut.

Rick Page, VE3IQZ for VE3KRG: We also had a QSO with NA1SS on the International Space Station!

John Lee, K6YK: Much better activity on the non-FM birds this time! Fourteen QSOs on AO-10 in 33 minutes!

Wayne Estes, W9AE for K9KM: In future AMSAT field day competitions, I suggest having separate categories for *single operator* and *multi-operator*. The highest score will probably be multi-operator, but it would be interesting to see what is the highest score for a single operator.

Jack Gelfand, K2BMI: I rigged up a telescoping pole mounted on the back of my Geo Tracker with 2M, 432 and 10 Meter beams. Rotated by *armstrong* method. Had a blast.

Steve Belter, N9IP for W9REG: We had a blast! Setup went smoothly, the station was ready to go 2.5 hours early, everything worked well, and the weather was beautiful.

Al, XE2AT: Thanks to all for a great time in the Field Day 2001, with the new rules that permit just one QSO in the FM satellites all of the load was supported by FO20, FO29 and RS 12. It was easy to work this satellite in mode A, free of 15-meter QRM! I invite Mexicans stations to work the satellites and give some points to the USA hams. I hope next Field Day to work DIGITAL and AO40!

James French, W8ISS for W8MRM: I started out a little late as I was up all day Friday and had to work the midnight shift. I finished setting up Saturday after FD started and then Murphy hit. The azimuth on my rotator gave out! I had to do the pointing the old fashioned way - yelling out directions while someone else *armstrong'ed* the assembly. We did pretty good compared to previous years where Murphy had better luck at more mischief with the computers. We didn't have any luck with KO-25 or UO-36. Even tried RS-12/13, but could barely hear the beacon on the early Sunday morning pass. Didn't hear RS-15. Missed out on working AO-10 this year with trying to work the digital birds.

Mike Scarcella, WA5TWT for K5ENG: Everyone had fun and I think we know a bunch more about working the low-orbit birds. AO-10 was really bad, except for the last 45 minutes, and then it was really moving!

***BV* for Al Tencza, NX2Q:** Here we are again at High Point State Park, NJ. AO-40 is orbiting at last, and the 2001 AMSAT Field Day contest is underway. What a feeling! Now add in Friday's wind, Saturday's rain and

thunderstorm, Sunday's visitors, and you have an exciting mountain expedition! BV (Back-to-the-Future Vehicle) even visited with lonesome AO-10 and had a little to say to the Fuji Brothers and their digital pal, UO-22. These Field Day trips, VHF contests and special events have allowed me to enjoy all the visitors, natural weather phenomenon, satellites, animals and humans. After eight years of developing my partner Al into a true adventurer, he has begun to drive me to drink (Hi Test – if you please). I have decided to look for a new partner who will not drive me up a wall. So if you want action satisfaction, I'm up for sale!

Roger Snyder, K4RS: The Fort Pierce ARC and Vero Beach ARC returned to a wonderful Field Day site at the Indian River Community College. We had a new larger travel trailer that provided a comfortable operating location for the satellite station. 2001 should have been a great year; instead it was almost a disaster. We always try to learn from our previous experiences. Last year our antennas blew over in a severe thunderstorm. This year we mounted our antennas on a very sturdy tower. We also started setting up earlier so we would have ample time to make sure everything was working correctly. We finished installing the antennas just after sunset Friday evening. I made lots of contacts Friday evening and Saturday morning while testing the station. Everything was working perfectly! We were looking forward to a banner year. As usual, we received our typical Florida thunderstorm early Saturday afternoon. It appeared that our preparations had paid off. The high winds almost knocked over our tent (and the awning from my brand new travel trailer), but the antennas did not budge. It soon became apparent that we had a serious problem. The SWR on the 70cm antenna was off the scale and received signals were non-existent. We finally discovered the cause of our problem late Saturday evening. The 70cm antenna had been installed upside down. During the afternoon thunderstorm the switch box had filled with water. We flipped the antennas and watched water pour out of the switchbox. Unfortunately, this did not cure the problem. To fix the problem we had to lower the antenna. With only a skeleton crew on the night shift, we did not have enough people to safely drop the tower. We had to wait for reinforcements to arrive Sunday morning. We finally got every thing fixed late Sunday morning and managed to make a few contacts before Field Day ended. While we did poorly point wise, this experience provided one more lesson to better prepare us for the future.

Jack K2BMI had it all, in and on his Geo Tracker for Field Day 2001.

Grant Zehr, AA9LC for N1SF Radio Club: We had a much more successful operation this year than last. We decided to focus on Fuji satellite operation, hoping to at least make our one contact. I was concerned that the satellites would be completely overloaded, but they held up well. Because of heavy traffic it was sometimes difficult to find the downlink signal, but we were able to make 3-5 contacts per pass with our modest station. We made 28 contacts in all with several dupes and one cross-mode contact. (Why are these disallowed?) I think the main thing is to focus on a mode that you are familiar with and try to duplicate your home

Doug WB5TKI (left) and Mike Scarcella, WA5TWT (right) getting ready to try some digital operation at K5ENG in South Texas.

The Sussex County ARC in north New Jersey had a great view from their hamsats station for Field Day.

station in the field; then hope that the satellites are up to the task! Field Day can serve as a training operation for the terrestrial modes, but with satellites (at least the LEO satellites), you must really be ready when the bird comes up! There isn't much time for learning on site, and the satellites will be more difficult to access than on normal days because of the increased number of users.

Larry Eker, WA0YQM for W6VOM: Great fun was had by all! We mainly used the FO-20 and FO-29 satellites, where there was plenty of activity. We also demonstrated the fun of operating through satellites that may have sparked interest in satellite communications with a few other hams.

Harold Reasoner, K5SXK for AI5TX: Had a good signal on the AO-40 beacon and am looking forward to AO-40 transponder operation next year!

Doug Chauvin, N8PYN for K8AYZ: This was my first year operating the AMSAT Field Day event, having taken over the position from Tom Mathison, WU8C. My station was only set up for SSB/CW and therefore missed out on some valuable digital points. It was refreshing to see that AO-10 is still putting out a valuable service while AO-40 is maturing.

Joe Mayfield, KA0YOS for W0WTN: We checked AO-10 several times with no luck, but what a thrill to work Susan Helms on the ISS!

Bruce Paige, KK5DO: About an hour before Field Day started, I did a demo on UO-14 with the ICOM W32A and arrow antenna. We had a nice crowd of hams that had finished setting up our K5HOU club station site and were awaiting the start of Field Day. The pass was crowded but I was able to make about five contacts. The demonstration went great and we looked forward to the fun of Field Day.

Dave Guimont, WB6LLO for K6HAI - North Shores ARC: As usual our satellite antennas drew a crowd. FO-20 came up out of the Pacific at 1800z. We sent a CQ with an elevation of about 30 degrees. An avid CW operator in the club was observing the satellite operation, but he had never made a CW or any other contact on a satellite. We immediately turned the key over to him, and he made two satellite contacts in about three minutes to give us our 100 ARRL FD points. We needed the radios for an operation on another band, but watching the thrill of the moment for him was worth the effort.

Breck Smith, K4CHE for W3HZW: Our humble entry, but we defy anyone to come up with a simpler station? In keeping with AMSAT guidelines we limited our operations to SSB/CW satellites and NO FM! The antenna was a single home brew 4 element 2 meter and a 6 element 432, patterned after the NBS calculations in the *ARRL Handbook*. Elements were mounted on a 1 inch square boom for ease of construction, with the UHF elements mounted 90 degrees to the VHF elements. Feed lines were snaked down through the boom for decoupling. The antenna used a *hairpin* match on 145 MHz and a home brew "T" match on 432. All elements can be folded back in place on the boom for transport. A flexible mike stand (gooseneck) was used to hold the antenna in place regards of the elevation, azimuth or polarization, thus single operator could quickly position the antenna for best reception and then just release it and go to the radio. The ICOM 821-H was housed in a home-brew, weather proof box, i.e. Military style with hinged doors on the bottom and top, micro switch CW key on the side and lots of clips to hold sat predictions, notes etc. Battery power was used for simplicity.

In a field in northeast Belgium, William PE1RAH and Dirk ON1DLL did it all, including digital operation via UO-22 during the AMSAT Field Day 2001 activity.

John Sheets, N8QGC made our voice contacts for us this year. John made three contacts on UO-14 (forgot about the one FM contact rule) and one contact on FO-20. We had a few at the site that were trying to listen in on their new FT-817's using Arrow antennas during FM passes.

Philip Berkowitz,KA1YIQ for N1EV: We encountered a few problems from a missing splice piece on our 70cm antenna (this forced us to use half of the antenna at 10 elements) to missing bolts for the 2 meter antenna and a bad cable that worked fine the day before Field Day but didn't work at the site! All in all, it was worth the effort to make a few contacts and get to show the general public what amateur satellite operation is about.

Ed Cole, AL7EB: I stayed home for Field Day this year and just played in my own field! My purpose was for more satellite operation, and to give support to the Alaska LEO Society - *5X5 Wilderness Expedition - AL7KK*. They opted to canoe across Hidden Lake, a small lake a few miles off the highway on the Kenai Peninsula about 40-50 miles to my east. They operated HF-QRP and satellite, and from reports on the repeater afterward, had a great time in the especially warm and sunny weekend (upper 70's). True to normal Field Day ops, my setup was fraught with mistakes and I got behind the time curve. I attempted UO-14 operation on the first pass of FD but my QRP/5W was quickly buried in the QRM, so I just sat back and listened while maybe two or three contacts were completed during the course of the pass - what a waste! I looked ahead at upcoming AO-27 and UO-14 passes and saw that there were some passes coming that would cross parts of Canada and Alaska while missing the lower 48! It was great, and included my bagging WH6BIE in Hawaii via UO-14. What a nice difference. Everyone took turns and nearly all made multi-contacts. I could have made a few more myself, but instead let others make a few. Later I listened to a couple more lower-48 passes and pandemonium reigned. Next year: Mode L/S on AO-40 - Be There! ■

2001 AMSAT Field Day Competition Results

Place	Call	Points	Class	Group Name
1	K4BFT	166	5A	Huntsville Amateur Radio Club
2	K5OE	103	1E	Jerry Brown
3	KE4AZN	100	1E	Mike Kingery
4	AA4MD	99	1B	Satellite Trailer Boys
5	W2LV	97	4A	Sussex County Amateur Radio Club
6	ON5LL	89	2A	PE1RAH + ON1DLL
7	VE3KRG	77	2A	Kawartha Amateur Radio Group
8	K6YK	77	1D	John Lee
9	K9KM	74	2A	Lake County RACES
10	K2BMI	72	1B	Keplerian Contest Club
11	W9REG	45	3A	Tippecanoe Amateur Radio Assn
12	XE2AT	39	1B	Alvaro De Leon (ex-XE2YVW)
13	W8MRM	29	2A	Motor City Radio Club
14	K5ENG	28	2A	Houston AMSAT + Houston ATV
15	NX2Q	27	1A	BV The Machine
16	K4RS	27	2A	Fort Pierce ARC / Vero Beach ARC
17	N1SF	24	4A	N1SF Radio Club
18	W6VOM	20	2A	Alameda County Sheriff's Comm
19	AI5TX	11	2A	Armadillo Intertie
20	K8AYZ	10	4A	L'Anse Creuse Amateur Radio Club
21	W0WTN	9	3A	Lake Area Radio Klub
22	KK5DO	7	1D	Bruce Paige
23	K6HAI	6	3A	North Shores Amateur Radio Club
24	W3HZW	5	3A	Recon Delta
25	N1EV	4	3A	Greater Norwalk Amateur Radio Club
26	AL7EB	2	1E	Ed Cole
27	WD5DZC	2	1A	Marty Smith & Crew
28	VE2DWE	1	1D	Luc LeBlanc
29	W5BTS	1	1D	Mahana Paige

Mike WB3ILM and Breck K4CHE set up a simple, yet effective, hamsats station for the W3HZW Recon Delta 2001 Field Day operation.

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From the Dungeon: Constructing a Single-Axis Fluxgate Magnetometer

Allan Copland GM1SXX

Editor's Note: This is a short article on the construction of a single-axis fluxgate magnetometer based on a kit of parts from Speake & Co. (UK) or Fat Quarters Software (USA). The end result is a wonderfully sensitive magnetometer capable of serious research work. The article includes details of how to calibrate the device. Bill Speake of Speake & Co. was a great help to GM1SXX in preparing this project and answered many questions. He also kindly gave me permission to reproduce information and photos from his data sheets. The complete magnetometer costs under $85.00 USD (£60 UK) and is a very versatile tool for the Radio Amateur with an interest in the Earth's geomagnetic field. The device can provide either an 8 bit parallel output to feed a PC or micro-controller or alternatively an analogue output voltage to drive a chart recorder or meter type indicator.

As Radio Amateurs, many of us have a strong interest in the variations in the Earth's magnetic field. Historically, the jam-jar magnetometer has been the measuring instrument of choice for many of us, being cheap and simple to construct. After watching a spectacular visual aurora in early April, I decided that I'd like to build an electronic magnetic field detector to detect such activity that could be easily duplicated by others. I wanted a system that could drive a PC directly to produce a permanent record of the magnetic activity in my area. I remembered reading several years ago about a range of detectors made by a company called Speake and Co. in Wales. Then I remembered the catch, I had spent a long time to no avail trying to find the address of the company. I did however find a reference on the Internet listing a U.S. distributor for Speake & Co's products called Fat Quarters Software; and before you ask, a Fat Quarter is a quilting stitch. I've often bought hardware from U.S. companies before but I really wanted to speak with the UK manufacturer about these devices before I ordered one.

This time, I got lucky. One of the UK electronics magazines had recently carried a project using a device from Speake and Co. Fortunately, although not mentioned in the article, Speake and Co.'s address was given elsewhere in the magazine, in another column. I had already decided that what I needed was an FGM-3 detector and an SCL006B magnetometer ASIC (Application-Specific-Integrated-Circuit) chip, AD557 D/A converter and the associated printed circuit board. I also ordered the component kit required to complete the project. These few items allow a simple single-axis fluxgate magnetometer to be constructed. I e-mailed Bill Speake, to confirm that what I thought I wanted made sense to him. He confirmed that the parts were indeed suitable for what I wanted to build and within a very few days, I had all the goodies delivered to the college where I work. Bill Speake has been very helpful to me throughout this project.

The items I ordered from Speake & Co are as follows:

- 1 off Magnetic Field Sensor – FGM-3
- 1 off Magnetometer IC chip - SCL006B
- 1 off PCB for Magnetometer - FQS001
- 1 off Parts kit for Magnetometer - FQS002
- DAC IC Chip – AD557

The cost of the above including value-added tax and postage is about $85 (£55.89).

The FGM-3 fluxgate sensor takes the form of a plastic cylinder, slimmer than an AAA battery and marginally longer. It is a potted assembly with four connecting pins protruding from the base. These sensors are a little bit unusual in that they are completely self-contained. FGM-3 requires a well regulated 5V DC supply and draws only some 13 mA and in return, provide an output signal in the form of square-wave pulses with the period dependent on the detected magnetic field strength.

The remainder of the circuit is very simple, thanks to the use of an ASIC chip, (labelled SCL006B). The ASIC does all the clever stuff and passes an 8 bit binary value (the field strength) to an AD557 D/A converter to produce an analogue representation of the field strength. On the PCB is also fitted a 7805 voltage regulator to supply the circuit with a regulated supply. The circuit has four sensitivity ranges and can be fitted with a selector switch if required.

In operation, the FGM-3 sensor produces a square wave output whose frequency depends on the prevailing field strength. The sensor has a +/- 50 microtesla measuring range (+/- 0.5 Oersted), runs from a 5V DC supply and produces a squarewave output in the 120kHz to 50kHz range. Current consumption is typically 12ma. The pulse frequency varies inversely as a function of field strength and the frequency range produced is ideal to drive computers or microcontrollers.

Speake & Co. also produce the SCL006 ASIC chip to partner the FGM sensor and make a useful magnetometer unit. Here is what Speake & Co. say about their SCL006B magnetometer chip:

- This IC (the SCL006B) makes it possible to construct, very simply, a single axis, sensitive magnetometer for earth field studies.
- The design to be described is intended as a robust replacement for the classic, but somewhat delicate "jam-jar" magnetometer, popular with Radio Amateurs for backup to propagation experiments. For this reason it duplicates the same type of output, namely the small angular fluctuations which occur in the direction of the earth's horizontal field component. In this way it should correlate correctly with other measurements taken by other amateurs in different locations.
- The design uses an SCL field sensor type FGM-3. The signal from this is fed into the integrated circuit which performs all the functions required to the level of providing a digital output on eight parallel lines which mirrors the tiny field fluctuations. This output can be fed directly to the input port of a computer for data storage or direct digital display.

For those wishing to use a meter or chart recorder, an additional IC, type AD557, is required to perform a digital to analogue conversion. Nevertheless, the design is simple, using few external components and should be capable of construction by beginners to electronics and those whose interests lie primarily elsewhere. The complete magnetometer circuit has been reproduced below (by permission of Speake & Co).

When I first looked at this circuit, it seemed strangely familiar, suspicious even. Peeling the paper label off the chip supplied revealed why. The SCL006B *ASIC* is actually a PIC microcontroller. A look at the circuit above will probably explain why these microcontroller devices are so popular, they need almost no external components to function, compared to normal microprocessor based solutions. The PIC in this circuit, a PIC16C54A operating at 10MHz produces an 8-bit data output which can be fed directly to a PC or alternatively, the 8-bit word can be used to derive an analogue value on pin 16 of the D/A converter. This analogue value can be then give a visual indication of field strength on a meter connected to the board. Alternatively, it may be used to drive a chart recorder to produce a permanent printed record of the field strength. The PIC and D/A fit on a high quality single sided roller-tinned 95*35mm PCB supplied by Speake & Co. as part of the Magnetometer Kit. (Figure 1)

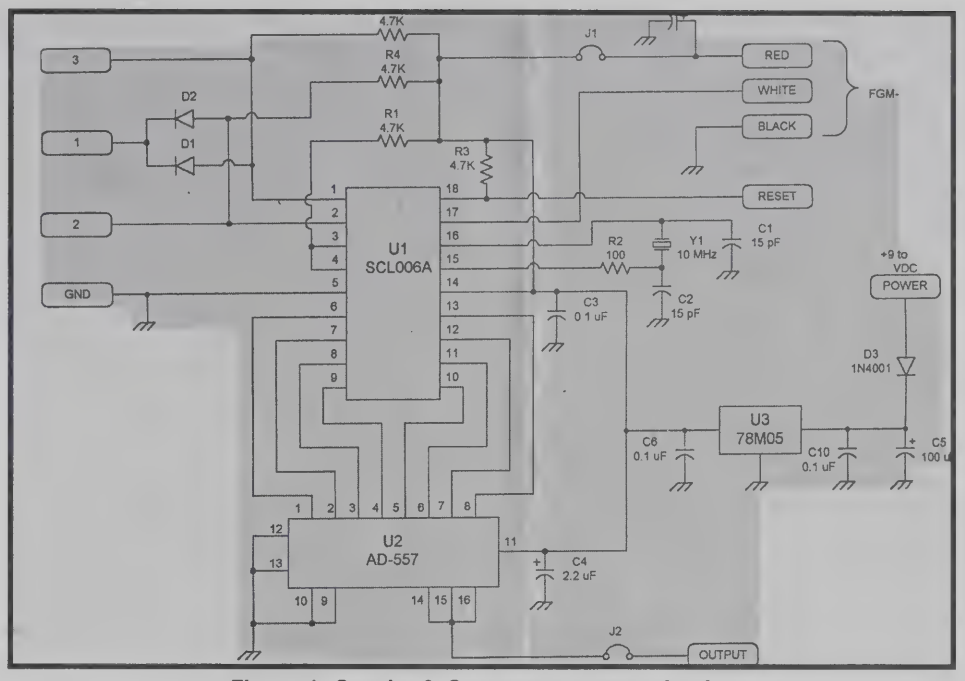

Figure 1. Speake & Co. magnetometer circuit .

It took me about 30 minutes to build this kit. It goes together easily, thanks to the excellent notes and printed component overlay and although it includes a microcontroller, could easily be constructed by a beginner. It worked first time and is very sensitive indeed. Sockets are supplied for the PIC and D/A chip but I decided not to use them. I just soldered the parts directly into circuit after double-checking that they were correctly aligned. You should use proper ESD protection when building this kit and the PIC and D/A chips should be fitted last. The good quality roller-tinned board makes building this kit a pleasure.

Here is how the PCB connects to the various external parts of the circuit: The sensitivity switch allows a measuring range to be selected by setting up a 3-bit binary control value on some of the PIC input pins. The sensitivity ranges are as below. Omitting the switch completely sets the measuring range to +/- 150 gamma (Figure 2).

Initially, for testing, I connected the PCB to the Fluxgate sensor by means of a length of ribbon cable. I later replaced this with miniature coax and a single length of stranded wire. I used coax to help reduce the level of RF leakage from the FGM output. The stranded wire takes the +5V DC regulated supply from the PCB to the detector. You can either use a 4-pin socket (only three are actually used) or solder direct to the connections on the end of the sensor. The sensor requires a tantalum bead capacitor connected between the +5V and 0V lines for decoupling purposes. Lead length on this capacitor should be kept to a minimum. I soldered the leads directly to the sensor pins making use of a heat shunt to avoid overheating the innards.

Being the impatient type, I was keen to know how sensitive this detector was.

I connected the board to my bench power supply and the analogue output to my DVM. The output voltage went to half scale and

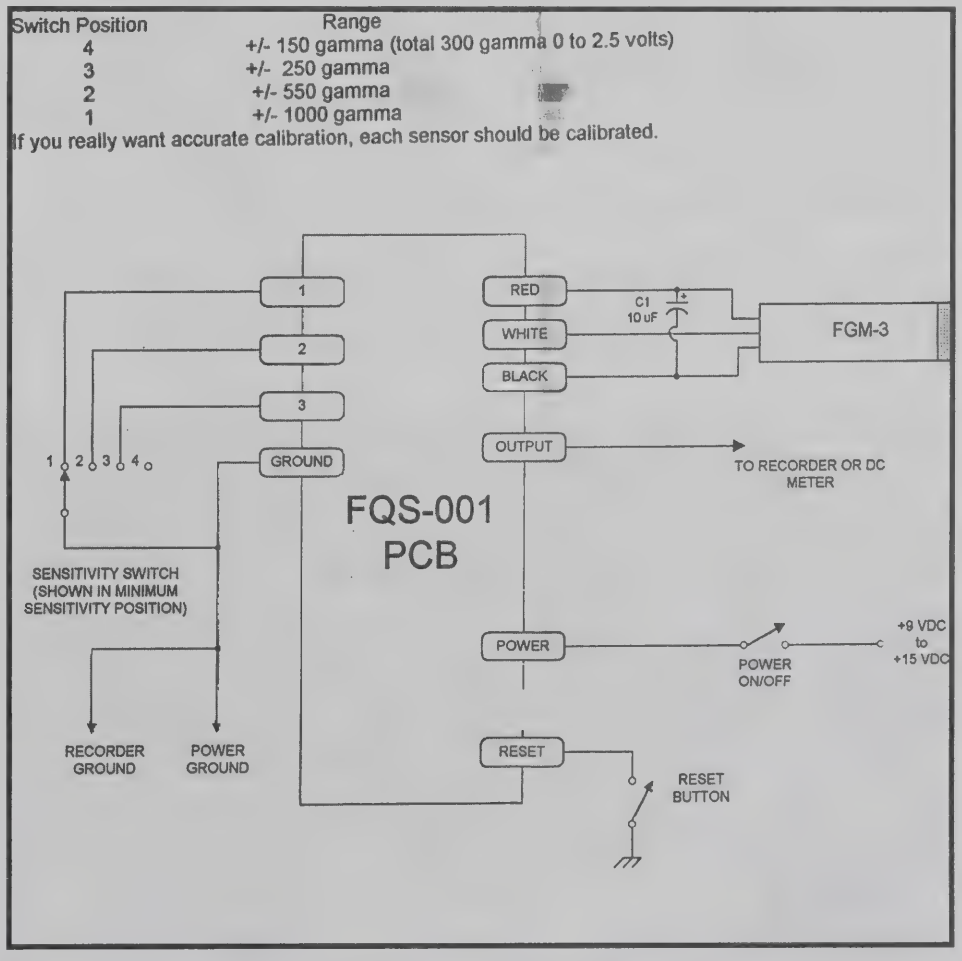

Figure 2. Connections to external circuits. (Courtesy of Speake & Co.)

stayed there (full scale for the D/A chip is 2.56 volts). This is exactly what should happen. Placing a small screwdriver a few inches from the sensor resulted in a sizeable change in the output voltage. It worked. Rotating the sensor through 90 degrees produced a huge change in the output voltage. Because the PIC integrates data over an eight second period, the output voltage is updated once every eight seconds. Initially, you may find this a little disconcerting, but this is exactly correct behaviour for this circuit.

For use as an Earth field magnetometer, the FGM-3 sensor should be aligned in an East-West orientation. I used some inexpensive plastic waste pipe as a housing for the unit. Some scrap foam holds the sensor in place within the pipe and a couple of end-caps keep the weather out. Built in the form of a letter 'T' the housing is durable, reasonably tidy and easily supported on a plywood block. I used a 1meter long length of 40mm plastic waste as a support for the unit topped with an 'equal T' carrying the sensor inside the body of the 'T' piece. Some scrap plastic sheet was used to seal the open ends of the 'T'. The 300 ohm impedance of the device means that long cables may be used if required.

Speake & Co. make the following recommendations regarding the interpretation of the data:

If direct digital input is chosen, it should be noted that there is no strobe, interrupt or handshaking facility available from the chip. This gives rise to the risk of data lines changing during input, causing incorrect reading. The program should take two readings in rapid succession and only accept data if they are identical, taking a third reading if necessary to obtain this identity. This problem does not arise in the case of a computer using an internal analogue to digital converter. The SCL006B output changes once every 8 seconds and the computer input scan rate need only be slightly higher than this to collect all the available data.

In short, no handshaking strobe signal is available from the D/A and the user's program must take this into account. On the plus side, the 8 bit data from the D/A is always 'enabled', so interfacing to a microcontroller or PC is a straightforward business.

Calibrating the Magnetometer

If the user wishes to calibrate the output, it is possible to achieve a reasonably good relative calibration with simple equipment. A single layer close wound coil into which the sensor can be inserted is all that is needed in the way of additional hardware. It can be wound on a cardboard or plastic tube using any wire available from enamelled to plastic covered link-up wire. Ideally the coil should be about ten times as long as its diameter, so it is advantageous to use the smallest diameter tube that the sensor will slide into. The sensor should be placed in the center during calibration but exact positioning is not critical.

The information needed for calibration is the length of the winding in millimetres and the total number of turns. Multiply the number of turns by 1000 and divide by the length to obtain the number of turns per metre, N. If a current of i amperes is passed through this coil the magnetic field at its centre, in units of amperes/metre is just N x i . To convert this to oersted N x i should be divided by 80. To convert to gamma multiply by 1250.

The field in such a coil will be uniform over the length of the sensor to better than 0.5%. To correct for the finite length of the coil multiply the figure obtained above by 0.992 for best results.

The current required is small. Typical plastic coated wire, for example close winds to about 835 turns /meter and 0.5 mA will produce just over 500 gamma. A simple series 10k potentiometer and milliameter connected to the 5 volt power supply will suffice. During calibration the sensor should be set in the east-west position away from potential sources of interfering magnetic field.

My magnetometer kit came with a comprehensive set of leaflets, not only for the products I purchased but also the other ASICs and products available from this specialist company.

If you have Internet access, Darrel Emerson's WWW pages contain some interesting data about magnetometry. His pages give details of one of the Speake sensors compared with the Tucson Magnetic Observatory's data and can be found at:

http://ourworld.compuserve.com/homepages/demerson/magnet.htm

Readers should note that I have no connection with Speake and Co or Fat Quarters Software except as a satisfied customer. All drawings used in this article and text highlighted in italics are copyright Speake & Co / Fat Quarters Software.

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AO-40: Winter for the 2nd Time in Three Months

Translated from the *AMSAT-DL Journal* by John J. Bubbers, W1GYD

In a previous AMSAT-DL Journal we reported that AO-40 found itself in a kind of winter sleep. The reason for this situation was the unfavorable sun angle that was greater than 45°, during which the sun could not be acquired by the sun sensors. Now you can read what has happened since then, and why AO-40 was in a winter sleep since the middle of April and how the 13-cm signals progressively improved.

07 February 2001: AO-40 in a Safe State

AO-40 is again in a season dependent limitation, which will end naturally at the end of April. In the event that the announced despinning routine is successful, then AO-40 can be put into an improved condition at an earlier date. The work and tests for these routines are going forward. The S2-MB on 2401.323 MHz is operating normally. The earth shadow passages during the perigee have no negative effect on the power budget of AO-40 at this time, which the WOD analyses indicate.

21 February 2001: Passed Sun-Angle Low Point

At this time AO-40 has reached its greatest sun-angle of approximately 78°. Now the sun angle is getting progressively smaller and the sun will again be visible to the sun sensors at the latest on about the 21 March 2001. Accurate attitude information will be available with that acquisition.

The flight attitude for 20 February 2001 is about ALON/ALAT 226/-7, extrapolated from the last indicated flight attitude (Jan. 18th: 248/-7). Remember that the flight attitude of the satellite in space is stable, the reference system for the ALON/ALAT, the orbital plane, is changed by the precession by several tenths of a degree per day. ALON/ALAT is valid only when referenced to a specific point in time. The illumination of the earth from the major lobe of the S-2 transmitter is changed by the change in flight attitude. As a result the audibility is reduced after the perigee (then optimum at MA 1 – 12), in contrast to successful error free data blocks which 3were received before the perigee at MA 251.

26 February 2001: AO-40 Status Report

The sensor electronics again generates input from the sun since the end of the passing of the earth's shadow in orbit 147. The telemetry channel #100 (analogue spin rate) indicates a value of #49. That is the same value that it showed in orbit 89, as we lost the input from the sun sensors.

Within several orbits we should expect that the sun sensor SS2 will likewise generate output, which again puts us in the situation of being able to receive flight attitude information, to begin reducing the spin rate using the magnetic control. The analysis of the temperature of the on-board computer (IHU) from DB2OS has indicated that the maximum sun angle with the lowest temperatures was distinctly earlier than had been anticipated. The IHU temperature reached its minimum of –8.4° C on February 1, 2001. That is nearly a month earlier than originally assumed. At the moment there is no explanation for this acceleration. The spin rate of about 17.5-rpm has not cot changed in the past weeks, and whatever contributed to its increase has stopped. As soon as the SEU delivers good sun sensor data, the spin rate will be reduced by the magnetorquer under the control of the IHU, which will make the further change in flight attitude easier.

The next milestone will be to activate the arc-jet propulsion engine (ATOS) with gaseous ammonia only, without the electrical power, to put the satellite into a good flightattitude. The test firing will be started to check out the control electronics and valves of the arc-jet. Even without the arc-jet's "ignition" the thrust of the tests will be sufficient to raise the perigee by about 100 km. Various independent analyses (including the French space agency CNES) have verified that the current orbit will be stable for many years, over the life expectancy of the satellite. The ATOS test should give us an additional degree of safety and a better feeling.

AMSAT-DL expresses its thanks to Paul Willmott, VP9MU, for his outstanding service in gathering and archiving AO-40's telemetry from various parts of the earth. These are vital additional information for the continuing efforts of the ground command stations to put AO-40 back into operation. All are encouraged to send in received telemetry in P3T format to the AO-40 telemetry archive at *ao40@amsat.org*.

Keep at it..You can find further information on the current AO-400 Internet site at: *http://www.amsat-dl.org* -73's Peter, DB2OS – AMSAT-DL

03 March 2001: IHU-2 Takes Pictures Again

The determination of AO-40's flight attitude continues. The YACE- camera and the IHU-2 were also turned on, in order to receive additional attitude information at the perigee in the proximity of the earth. The first pictures were downloaded and show parts of the earth's surface. The pictures are in the AO-40 telemetry archive.

07 March 2001: AO-40 Update

The IHU-2 and the YACE camera are functionally sound, and pictures were made for a quick flight attitude determination. The information from the highly compressed

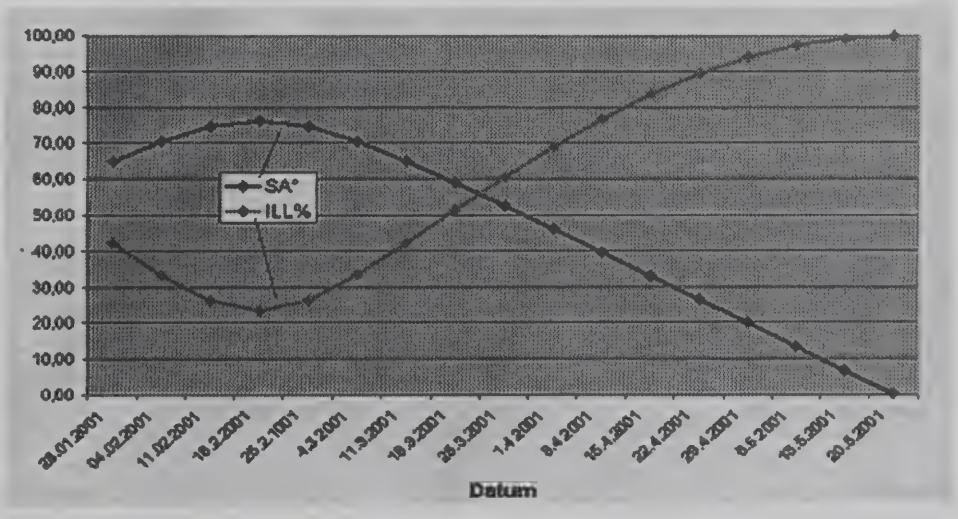


Figure 1. The expected progress of the Sun angle and illumination on AO-40 without active attitude control using magnetorquing.

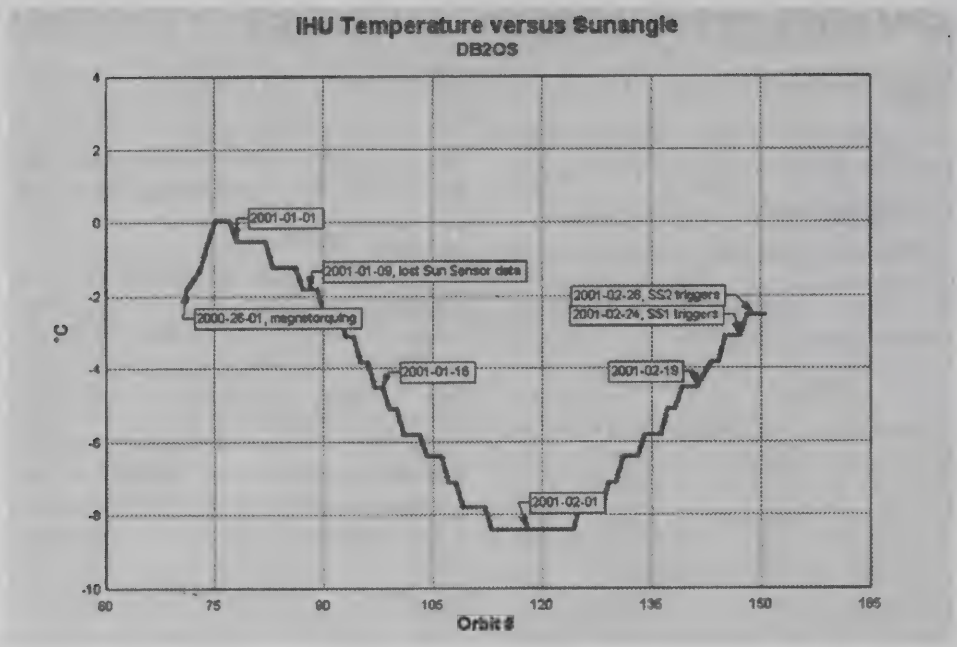


Figure 2. The relationship between the on-board computer's temperature to the Sun angle confirms the unexpected shorter winter sleep phase in February 2001.

JPEG images was indecisive, however. More pictures will be made when the communications are better, and the spin rate has been reduced.

The magnetic attitude control is successful in reducing the satellite's spin. The original 17.59 revolutions per minute the spin could be reduced to 16.73 during the first perigee and was reduced to 15.9 in the second. This represents a reduction of between 0.8 and 0.9 revolutions per perigee. The goal is about 5.

The gathering of WOD continues in order to gather more attitude information.. As soon as the spin permits the flight attitude of the satellite will be changed to improve the communications connections.

73's, Peter, DB2OS, AMSAT-DL

09 March 2001: Spin Rate Further Reduced

James Miller, G3RUH, provided the following information:

The rate of reduction amounts to –0.74 revolutions per perigee.

Theoretically AO-40 could be reduced by 5 rotations in 11 orbits or 8 days.

Orbit	RPM
156	17.58
157	16.73
158	15.86
159	15.20
160	14.65
161	13.90
162	12.99

(Orbit 162: March 8, 2001 (THU) 0910 UTC)

12 March 2001: Heat Pipes Operating Again

Further good news: The heatpipes appear to be operating.

The S2-transmitter operates at about 35 to 37° during the past few weeks: its temperature is now between 19 to 20° C, which means that the heat pipes are working again after the spin rate was reduced.

The measured value of the analogue spin rate is now close to the calibration range again, which indicates 9.6 rpm.

The actual magnet control procedure works very well and will be concluded shortly. The flight attitude is roughly at 206/30 and 10 rpm.

With ALAT outside the orbital plane we can change ALON only and ALAT as well as to undertake the further spin reduction.

The next magnetorque command will be uploaded during orbit 167 and anticipates bringing the flight attitude of the satellite to 248/45 and 5.8 revolutions in the next 10 future perigees. The sun angle will then be at 38°.

Here is the table for the expected and measured values for spin and sun angle.

	Expected		Measured	
Orbit	RPM	SA	RPM	SA
156			17.59	39
157	16.93	38	16.73	38
158	16.18	37	15.87	37
159	15.43	36	15.20	35
160	14.70	35	14.66	34
161	13.95	34	13.91	33
162	13.22	33	12.99	32
163	12.50	33	12.11	30
164	11.80	31	11.36	28
165	11.11	30	10.74	27
166	10.41	29	9.82	25

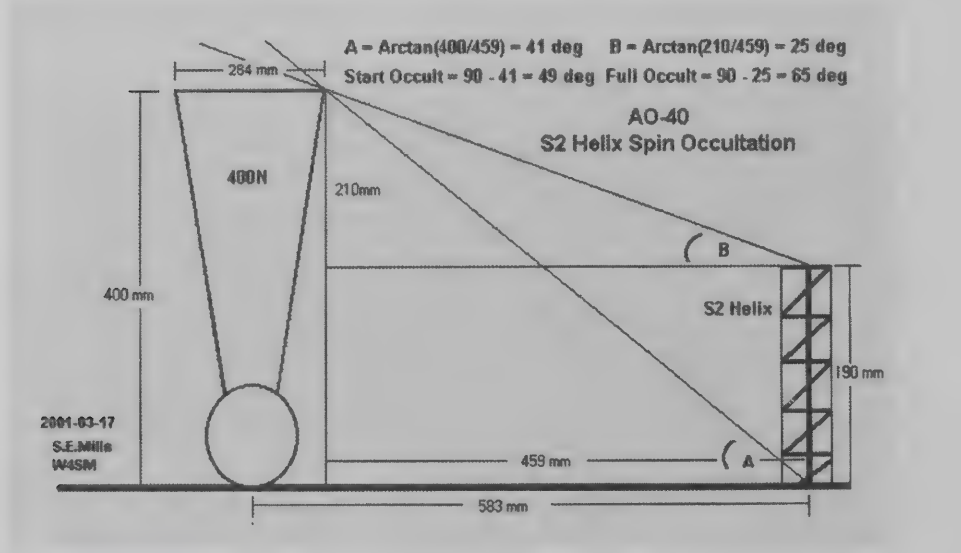


Figure 3. AO40 Command Station W4SM illustrates the geometric relationship of the S2 antenna arrangement and possible fading occurences during the squint angles from 49-65 degrees due to the 400-N engine.

17 March 2001: Explanation of the Event on 13 December 2000

At the 8th AMSAT-DL Symposium, Karl Meinzer, AO-40 Project Leader, described what has happened since the launch. He explained especially, that the event of 13 December 2000 is technically completely explained and the human components, which

lead to the occurrence, is understood. The goal is to eliminate similar problems in the future, and to forge forward in setting AO-40 into operation. The trigger of the *catastrophe* was the closed pressure relief opening of a valve on the 400-N thruster. As a result, the remaining fuel stayed in the cooling chamber of the thruster and, it is assumed, exited forcibly by a small explosion from a resulting leak.

During the event there was a *brown out*, a partial collapse of the on-board voltage, which lead to the shutdown of the on-board computer.

Aside from the loss of one of the multiplexers and thereby several current measurements and the defect of several temperature sensors is until now not certain, the omni-antennas on the rear face of the satellite no longer operate with the receivers.

The tested components operate as expected with the high-gain antennas. In light of the events the reactivation progress of the satellite is a special achievement. Comparable successes after a similar engine event are not known to AMSAT until now.

Karl Meinzer explained the situation on AO-40. After the successful magnetorquing the satellite will be maneuvered into a flight attitude to be able to test the ATOS arcjet propulsion engine. Future plans for operational use and for orbit correction by ATOS depend on the results of the test. If the ATOS test is satisfactory, then the first transponder operation could be tried distinctly earlier than originally planned, as early as the first half of 2001.

20 March 2001: Receiving Situation Explained

AO-40 command station Stacey Mills, W4SM, explained with graphics in Figure 3 why there are no error-free data blocks from AO-40 telemetry to be received between squint angles of 49 and 65 degrees.

The bell of the 400-N propulsion system shadows the antenna of the S-2 transmitter increasingly, beginning at about 49 degrees. This results in a deep fading loss of the signal. On 16 March 2001 the flight attitude with ALON/ALAT 212/45 and a spin of 5.8 revolutions per minute were indicated. The flight attitude change is in progress using magnetorquing.

28 March 2001: Spin Up to 5 r/m in Process

The last magnetorquing unit ended on March 20th, but will shortly be started again. At that time the spin rate was at 1.8 rpm, the planned value. The reduction rate value was at –0.7 rpm/perigee at the beginning and late at 1 rpm/perigee. It total, the reduction rate was greater than expected, which brought us to 1.6 rpm in 21 perigees from 17.6 rpm.

The flight attitude is still being measured, but until now there were several confusing results. Without magnet attitude control we observed an attitude change of 5°/day or 4°/perigee, although the maximum value is 0.85 degrees/day relative to the sun's motion and the precession.

These higher rates of change could explain why the previous winter phase was shorter than the conventional opinion had previously calculated. Using several WOD analyses it was found that the attitude changes only occur when the satellite is at the perigee. The friction during the perigee was taken into account but it is apparently greater than expected and calculated in advance. This may be attributable to the sun's activity.

Without active attitude control the effect would continue, and in about ten days we would again lose the triggering of the sun sensors.

It was therefor decided to increase the satellite's spin to reduce the rapid change of attitude from the friction. This will give us some breathing room. A magnetorquing over 5 perigees was initiated for an early start. The goal is a spin rate of 5 rpm.

The preparations to test the arc-jet are continued as soon as the flight attitude is determined and correctly positioned.

30 March 2001: Telemetry Transmissions Silenced

In the morning hours the S-2 beacon of AO-40 went silent during the perigee transit between the Indian Ocean and New Zealand. The presumptions are in the direction of *soft error* in the RAM of the on-board computer because of radiation from the exceptionally high sun activity.

02 April 2001: Magnetorquing Shows Unwanted Progress

The active flight attitude control is not proceeding quickly enough to save it from another early 'winter sleep'. Seemingly, the frictional forces of the high, thin atmosphere in the perigee work against the magnetorquing forces.

04 April 2001: Plans for April Until June 2001 - Time Schedule Changes

Figure 4. The Earth's image taken by the YACE camera. This and two further images provided the calculation of AO-40's flight attitude.

In the past few days our plans for AO-40 had to be changed. We have determined that there is a nominal effect because of the atmosphere, we think, at the perigee. It leads to a reduction of ALON of a good 3°/perigee at a spin rate of 2 rpm. From the precession of the orbit plane there is another 0.7° added, which leads to about 4°/perigee of about 5°/day.

In spite of the passage through the earth's shadow the magnetorquer is only slightly greater than this effect, and we had to determine that we were in a position to cancel the effect and to additionally increase the effect by 1°/perigee. However, it is clear, that at this rate it will take a long time to go from 170 to 270. Additionally the altitude at perigee is seasonally reduced because of the sun and moon influences, and we could lose the plus value of ALON during the maneuver. The movement of ALON from 170 to 270 was

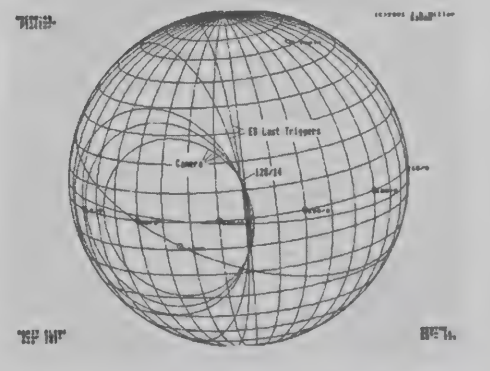


Figure 5. The flight attitude determination with the attitude plotter of the Command Station G3RUH. The three position circles from the camera sections are visable, as are the large arcs of both Earth sensors and the Sun line. The flight attitude 128/14 is at the remote intersection of the Sun line.

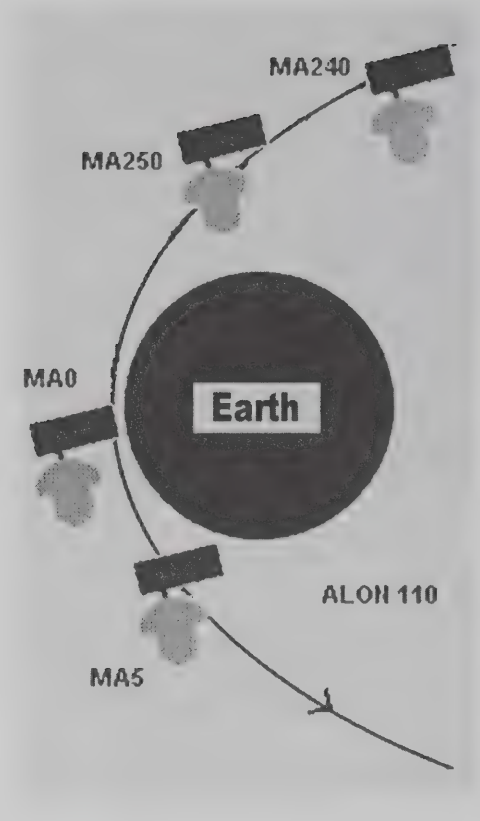


Figure 6. A simplified view of AO-40's antenna pattern to Earth at ALON-110. It shows the coverage with a minor lobe at MA240 and the main lobe at MA250. With increasing attitude change toward ALON=0, the main lobe will point towards Earth earlier and longer. The optimum would be at ALON/ALAT=0/0 at apogee.

therefor halted. Instead we will change ALON in the other direction to 90 and then through 0 to 270 hopefully later in this year. There are several advantages to this plan.

- Firstly, we can use the atmospheric effect to accelerate the magnetorquing and an earlier change in ALON.
- Secondly, the communications be cause of the improved flight attitude will rapidly improve.
- Thirdly, when we reach ALON = 0 we will be in the position to perform sev eral transponder operations sooner rather than later. That should be wel come.

During this process the satellite will go into "winter sleep" again. This is the designation we have given this phase in which thee sun sensors cannot see the sun. If the atmospheric effect lasts as it did until now, then the phase of the poor sun angle (>45°) will be short. During this period there is the possibility that the sun will be above the spin axis. In any event, the underside of AO-40 will be illuminated, so there is no danger to the cameras.

Expected Time Schedule

Following our predictions, the way things can evolve. After the 5th of April the sensor will lose contact with the sun. Then we will have to wait 4 to 6 weeks until the sun angle reaches its zenith. At this time ALON should have come to useable beacon communications. Although the sun sensors won't deliver any data, the temperature profile gives a clue of the sun angle. This shows previous telemetry records.

This table shows our expectations. AO-40 is nearly six months old and we learn from it and it tries to impart something to us.

73s Peter, DB2OS, AMSAT-DL

Date	ALON/ALAT	SUN AZ/EL	SA	ILLUM
05APR01	146/0	280/5	-44	72%
18APR01	110/0	289/11	-79	19%
25APR01	90/0	294/14	-63	45%
03MAY01	70/0	299/17	-39	77%

12 April 2001: Updated News on the Beacon Loss

Guenter Wertich, DF4PV reports that the S-2 beacon went silent on 12 December 2001 at 0046 UTC at MA 8. The beacon surfaced again at MA 128. The spin rate is 2.2 rpm, according to measurements of the signal strength variations from Helmut DL1IN. The signal quality will improve with the passage of time because of the flight attitude.

14 April 2001: No Beacon Transmissions between MA 3 and MA 80

Turning off the S-2 beacon between MA 3 and MA 80 serves to conserve energy during unfavorable sun angles. The flight attitude goes proceeds quickly:

Orbit	ALON	SA	TEMP
202	143	-49	10.0
203	139	-51	10.0
204	136	-53	10.0
205	134	-56	10.0
206	132	-58	9.4
207	129	-60	8.7

ALON is based on the evaluation of the earth sensors. The sun angle (SA) is based on the assumption that ALAT 0°. As stated previously, we lost sun contact of the sensors at the end of orbit 201, and AO-40 is officially in "winter sleep". The magnetorquers are off and cannot be used until the satellite locks onto the sun.

If the above data are extrapolated, the sun sensors should function again during orbit 228 on April 29, 2001. Then the sun angle will be -45° and ALON will be = 74.

DF4PV reported that he suddenly lost the S-2 beacon signal on April 12, 2001 at 0:46 UTC. (Thanks for the observation!) The IHU provides a routine that monitors critical situations. One of the assignments is the monitoring of the battery voltage. At that time the IHU is turned off when the voltage falls below 26 V. This was actually the case because of the poor sun angle and the eclipse. Although 26 V is not critical, we prefer to be as careful as possible during the unfavorable sun angle. The IHU turned the beacon on again at 09:36 UTC at MA = 128.

If one looks at the Event #5 in the telemetry from orbit 205 one recognizes that this occurred one orbit earlier. The event shows that on April 11, 2001 at 06:09:38 UTC at MA = 12 the S-WATCH routine turned off the S-2 beacon. At MA = 128 it came back.

The IHU-2 was turned on again to take three pictures in a three minute interval at MA = 250 during Orbit 207.

73s Peter, DB2OS for the entire AO-40 Command Team

15 April 2001: Flight Attitude Precisely Defined by Camera Pictures

James Miller, G3RUH, furnished the following information: four pictures were made at MA 250 in orbit 207. The JPEG quality was set at Q = 20, in order to keep down the size of the data file. The JPEG's contain 256 gray levels. The IHU-2's clock was calibrated and was correct to within a few seconds of deviation. Based on the last Keplerian elements the following reception conditions were valid:

	2001 Apr 13	Rev 207	
Image	Filename	UTC	MA
P1	133206.JPG	1332:06	250.17
P2	133504.JPG	1335:06	250.84
P3	133803.JPG	1338:06	251.53
P4	134101.JPG	1341:06	252.20

The spin rate was 2.047 rpm. At the indicated time the AO-40 camera viewed in the direction of the earth onto the Gulf of Mexico. Additionally, the following is to be noted:

- The satellite rotates about 14° during an exposure, so the distortions are mini mal.
- Circular displacements (similar to a cra ter) can be recognized at the top and bottom edge. As always, they are not in the same position as on the pictures from orbit 152.

• The edge of the earth is visible in three of the images, and the angular distance of the center of the image indicates a flight attitude of ALON/ALAT 128/14 with needle-like convergence (highly accurate). See image above.

• This confirmation agrees with the last trigger values of the earth sensors at 12:32:08 (lower) and 13:07: (upper) which was like that of the last year before the intermediate event.

• On the assumption that the attitude 128/14 is correct, the sun angle for these pictures was -55°, thus the sun was at 35°to the Z-axis. The camera looks into the +Z-direction.

The following conclusions result:

• The camera (YACE) and the attendant parts of the IHU-2 are functioning.

• The earth sensors and the camera mounting are unchanged.

• We now have a firm concept of the flight attitude

18 April 2001: The Signals Become Increasingly Better

The audibility and signal strength of the S-2 beacon becomes increasingly stronger with the continuing change of the flight attitude (especially ALON) in the direction of ALON/ALAT 90/14 (expected about 25 April 2001). For the next orbits the following values (see Figure 9) for ALON are anticipated (ALAT is indicated at 14, the spin rate is about 2 rpm).

Meanwhile, the correct telemetry blocks can be written with simple S-band installations (16-turn helix, 35-cm parabolic reflector, short backfire or 20 element loop Yagi's). And this, although the antenna squint angle is between 35 and 70 degrees.

22 April 2001: Flight Attitude Develops Positive

The IHU-2 and YACE were again programmed to take several pictures in the vicinity of the perigee. Eleven images for the flight attitude determination could be taken during the perigee of orbit 216.Thereby the flight attitude of the satellite was determined and was ALON/ALAT = 106/11 on 20 April 2001.

The images show the characteristic *rings* and *bubbles* which are recognizable in the YACE pictures since the event of 13 December 2000.

A modified example image is shown which shows Mexico and the southwestern USA from the YACE's direction. To minimize the amount of data the pictures are highly compressed and contain no visible details.

28 April 2001: Transponder Successfully Tested

During the 226 orbit the pass bands of the U- and L- band receivers were connected to the S2 dowlink transmitter. Both of the command stations G3RUH and W4SM tested the transponder briefly with PSK, CW and SSB signals in the uplink. The tests with a transmitter powers of between 10 and 30 Watts were extraordinarily successful in spite of an unfavorable squint angle up to 40 degrees and this confirmed that the IF matrix functions in these combinations.

01 May 2001: RUDAK Reactivated

The RUDAK packet radio unit for digital radio operation was turned on again. Early tests were performed. The energy budget of the satellite was positive thereafter, and additional heating of the satellite was +1 degree.

02 May 2001: RUDAK Transmits Telemetry

The RUDAK command station Jim White, WD0E, was able to load the primary housekeeping, whereby RUDAK telemetry became available. A first look confirmed that all values were within normal range. Reception reports indicated good reception of the 9k6 RUDAK downlink in the S-band.

The active flight attitude control by magnetorquing was also begun again. The first targeted flight attitude 0/0 for optimum transponder operation can thereby be achieved more quickly. The following goal is ALON/ALAT 270/0, in order to test the ATOS propulsion engine to increase the altitude in the perigee.

Rev	Alon	Rev	Alon	Rev	Alon	Rev	Alon	Rev	Alon	Rev	Alon
210	122	213	115	216	108	219	101	222	94	225	86
211	120	214	112	217	105	220	98	223	91	226	84
212	117	215	110	218	103	221	96	224	89	227	82

Fig. 9: Expected values for ALON.

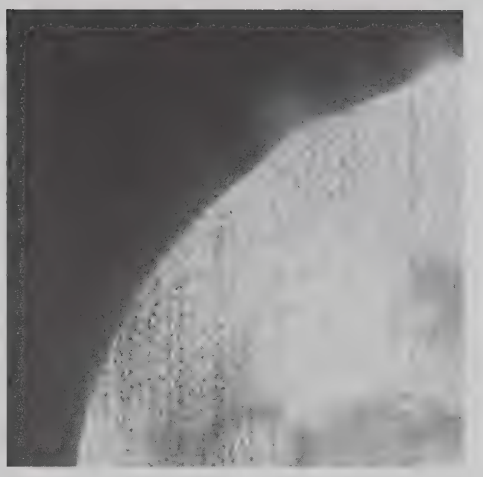


Figure 7. A somewhat reworked (gamma correction, increased contrast, noise reduction) image from the YACE camera from AO-40 orbit 216. The image is highly compressed and thus shows no details. Characteristic after the event of 13DEC00, *rings* and *bubbles* distort the image. (Residue from the fuel remains on the lens?)

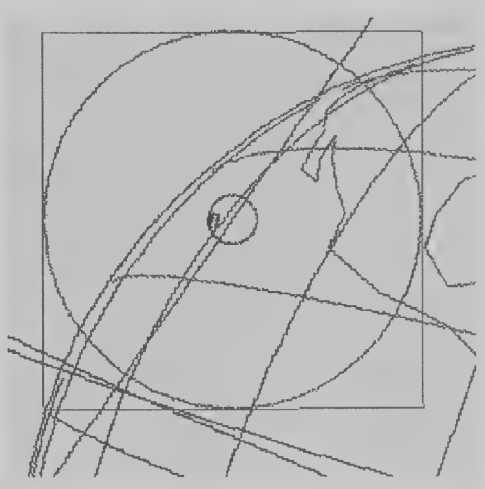


Figure 8. A computer section of the Earth's surface from Figure 7. Southwestern USA and large parts of Mexico are in the picture's range.

Preparation for Transponder Operation

In consideration of the development of the flight attitude in the direction of ALON/ALAT = 0/0, transponder operation can be considered in May. After the successful tests with the U- and L-Band receivers the most likely combinations are U/S2 and L/S2 at squint angles of less than 30 degrees.

Please do not make any uplink attempts as long as the radio operation is not opened. Take notice of the current news reports on our home page, on the Info-Mailinglist, on the satellite beacons or in the packet radio rubric AMSAT.

Experimental transponder operation will begin on Saturday morning, May 5 at about 08:00 UTC (MA 135). The U-band and L1-band uplinks will be connected with the S2 transmitter in the IF matrix. If no problems appear, the transponder will be useable until MA 240. Changes in the schedule will be announced over the telemetry beacon.

Since this is an experimental transponder operation, the transponder cannot at any time be turned off or the turn-on times can be turned off without previous warning. To be noted, radio communications should take place +/- 5 kHz from the middle beacon (MB). The window for transponder operation is about ten days long before the flight attitude is further changed in order to test the arc-jet for an increase in the perigee altitude.

It is also anticipated to test the U- and V-band transmitters at good squint angles and good visibility. ■

A Retrospective of the 8th AMSAT-DL Symposium

Frank Sperber, DL6DBN/AA9KJ (*Translation: John J. Bubbers, W1GYD*)

With more than 100 visitors, the 8th AMSAT-DL Symposium again took place successfully in Detmold. Under the regular routine planning by Ulf Drewes, DL3YFA, and his team, AMSAT-OSCAR 40 was in the center stage of the lectures and demonstrations.

Detlev Hollman, DK2HD made the morning's opening presentation with a new microwave-transverter concept, which is wide-band, multiband and duplex capable. In two separated modules, a base device with service systems and a remote translator unit close to the antenna, the units cover all micro wave bands from 1.2 GHz to 24 GHz with transmit and receive capability. For an IF a 145 or 435 MHz receiver can be used. In combination with a dedicated antenna combination all UHF bands can be operated on AO-40. The transverter is in the conference notes, in which other examples are described (see below).

Next was the young ham from the Netherlands William Leijenaar, PE1RAH, who demonstrated his own development of a linear transponder for Mode-B (70 cm and 2 m) and Mode-J (2m and 70 cm). In the next *AMSAT-DL Journal* we will present this small transponder (*Editor's Note: For a similar article, see Nov/Dec 2000 issue of* The AMSAT Journal.).

As the last presentation before the mid-day break Frank Sperber, DL6DBN discussed how one can be occupied with the satellite during the preparation phase of AO-40 without transponder operation. Reception of the 13-cm beacon and the decoding of the telemetry are good preparation to become acquainted with the particular immediate characteristics of the S-band and the satellite. Beyond the presentation of the necessary HF components he also introduced the hardware decoder and software solutions for the reception of AO-40 telemetry. A part of the presentation can be read in the last *AMSAT-DL Journal*.

The mid-day break was again used for meaningful discussions centered on amateur satellite radio. Erich Eichmann presented updates for the SatPC32 and WisSat32 programs. The working group, Amateur Radio and Technology in School, was represented by Ulrich Wengel and the CD-ROM collections and Practice Notes of the AATiS. The display stand of the AMSAT-DL merchandise distribution was under the guidance of Martin Blanz and his XYL Elke and was busily surrounded during the mid-day break. As in other years, the RegTP were prepared for conversation and measurements in their radio measurement vehicle. And what would an AMSAT-DL Symposium be without the famous *Fish and Chips by Bill*. At the end of the mid-day break for him everything was *sold out*.

Peter Guelzow, DB2OS, followed with a gripping report on the successful start campaign of Phase 3D/AO-40 in Kourou at which the official launch video was also presented. Karl Meinzer, DJ4ZC followed with the current status of AO-40 and the near future preparation for putting it into operation (see also the AO-40 report in this issue). Accordingly, AO-40 can still become a successful Amateur Radio service satellite, even after the intervening event in December 2000. At the conclusion of the day, the membership meeting of the AMSAT-DL elected a new Board of Directors among other business (see the minutes of the meeting in this *AMSAT-DL Journal*).

In the coming year the call will again be: *Welcome to the 9th AMSAT-DL Symposium.* Remaining conference papers and a conference video are available by request from the conference leader: Ulf Drewes, DL2YFA, Hörster Str. 94, 32791 Lage, Germany, E-mail: *ulf.drewes@gmx.de.*■

A Side-by-Side Comparison of the FT-847 and the IC-910H

Mark D. Johns, K0MDJ

As satellite operation has grown in popularity, major Amateur Radio manufacturers have noted a market for radios designed for satellite operation. Unfortunately, because the Amateur Radio market generally is not large, and the satellite portion of that market is an even smaller subset, manufacturers have not had the economic incentive to design radios specifically for satellite use. In every instance, satellite capability is a feature added to a rig that is aimed broadly at VHF/UHF and sometimes HF operators of all sorts. Such integration always leads to compromises, and some manufacturers have managed these compromises more effectively than others.

All three of the major manufacturers, ICOM, Kenwood, and Yaesu, have made entries in the satellite market. Yaesu started the effort with its FT-726, which was embraced by the satellite community as a worthy first effort, but was also recognized as having some major flaws. Most of these flaws were corrected with the introduction of the FT-736R, still a venerable radio in satellite circles and one that continues to command high prices on the used market. Among the '736's more endearing features was an *open architecture* design which allowed users to add band modules in the field – for satellite operators, the ability to add the 1.2 GHz band was of particular interest. The most recent Yaesu offering — the FT-847 — abandoned the open architecture approach, but offers HF coverage, making for a single box with capability all bands from 160 meters through 70 cm. (222 MHz, inexplicably, excluded). The '847 has become the de facto standard of satellite operation today.

ICOM is also on its third generation of satellite capable radios. Coming into the market somewhat later than Yaesu, ICOM also had something of a false start in the IC-820. This radio had so many inconveniences for satellite operators, in particular, that it was rather quickly withdrawn from the market and replaced by the IC-821. The '821 solved many of the problems associated with the '820, but its popularity among satellite operators never matched that of the Yaesu competition. Generally, ICOM made satellite capability an afterthought on its VHF/UHF multi-band rigs, and while possible, working the birds with these ICOM radios was rather cumbersome, at best. ICOM has recently introduced a replacement for the IC-821 – the IC-910H. The '910 is similar in design approach to ICOM's earlier efforts, but the styling of the radio is based on that of some of the company's more recent HF transceivers. Even more intriguing for the satellite operator, ICOM has borrowed Yaesu's now abandoned *open architecture* approach by offering an optional 1.2 GHz band module. With the prospect of AO-40 functioning primarily in an L/S mode, this option is of significant appeal to satellite operators.

While both of these radios, the FT-847 and the IC-910H — along with the latest Kenwood entry into the satellite market, the TS-2000 — have had individual product reviews in various ham magazines, most of these reviews have touched only briefly on satellite operation. Further, to my knowledge the radios have not been evaluated in the magazines in a side-by-side test.

Allow me to be up front about my biases: I have used ICOM equipment on the HF bands for many years, and have been more than pleased with a fairly wide variety of the company's products for over two decades. On the rare occasions I've had need of it, I've also been generally pleased with ICOM's parts and repair services (with the exception, some years ago, of one radio that had to go back to ICOM several times for repair of the same problem). I use several ICOM transceivers on HF at home and in my mobile, as well as ICOM VHF/UHF FM rigs in my cars, and I even have an ICOM hand held. For many years I used a set of IC-271, IC-471, and IC-1271 on AO-10 and AO-13, as well as on various PACSATs. Because I have a lot of ICOM microphones and accessories laying around the shack, it makes sense to be consistent. So when I try an ICOM satellite radio, I really WANT it to work at least as well as, if not superior to, the competition.

When the IC-821 was introduced, I had the opportunity to do a side-by-side comparison of that radio and a Yaesu FT-847 before making a purchase. Not only was the ICOM more cumbersome to operate, the Yaesu produced consistently better signal reports from other operators on the birds. So somewhat reluctantly, I bought the FT-847 and have used it since. Despite my ICOM bias, I have to say that the '847 is a fine radio, and has been a joy to operate in both the analog and digital satellite modes. But when the IC-910 was introduced earlier this year, I was anxious to see if ICOM got it right this time. I was also anxious to be able to add 1.2 GHz capability to my station. In addition, the IC-910 offers significantly more output power on the 144 and 430 MHz bands, and a few more (and larger) knobs and switches, which theoretically should make operation easier for an aging and increasingly nearsighted Baby Boomer.

After trying unsuccessfully to get more information about it's features, I finally resorted to buying an IC-910H just so that I could read the manual and see how it would perform. I managed to find one almost brand new on eBay from another operator who apparently had the same plan. Though I would push my credit card limit to the max, I knew that I would be selling my new purchase once again soon after the trial period – or if I kept it, the FT-847 would go on the market and fetch a good price. So with my net worth momentarily near zero, I was able to have both radios on my operating table, side by side for comparison. The antennas used for this test are KLM 2M-22C and 435-40CX, both with switchable polarity, and I have Landwehr pre-amps on the tower for each band. I used FO-20 and FO-29 as my primary test birds for the analog modes.

The FT-847 and IC-910H have some remarkable similarities: Both take identical antenna connectors for each band and even have interchangeable power cables, both include CW keyers and direct connections for 9600 bps packet, both use a menu system for set up of various microprocessor controlled parameters, and both will require the new operator to spend considerable time studying the manual. The learning curve is rather steep on both rigs. While the '910 offers more power and the 1.2 GHz band expansion option, the Yaesu comes with HF, audio DSP and internal pre-amps standard. DSP is an optional module on the ICOM, and at the time of this test my '910 is not yet so equipped. However, I found the ICOM better on receive. Even without the internal preamps, downlink signals were at least as loud on the ICOM, and even compared to the '847 with DSP noise reduction on, my ears guess that the receiver noise figure is better on the ICOM, with less fatiguing rush underneath received signals. Further, Yaesu has had some audio level problems with the headphone jack, at least on earlier versions of the FT-847, while the ICOM delivered full audio to my earphones. I have some nasty, pulse type electric line noise that comes and goes near my QTH. Although both rigs have

noise blankers, the blanker on the '910 did a noticeably better job of filtering out the noise. All in all, the advantage goes to ICOM, and would probably be enhanced even more by adding the optional DSP unit.

While Yaesu equips the FT-847 with an audio speech compressor, it does not function in the satellite mode (though some Yaesu techs have claimed that it is on all the time in satellite mode, even though the panel indicator does not show it). The IC-910H compressor does, in fact, function in the satellite mode, and listening to my downlink verified that it adds good punch to the transmit audio, without introducing distortion, when used at the factory pre-set level. Of course, the extra power makes the ICOM louder on the downlink if one wishes, but this is not necessarily a virtue on crowded transponders. When power was throttled back on the '910H to the Yaesu's power level I received good reports from both transmitters. Replacing the supplied hand microphones with a Heil headset improved the audio reports received on both radios. Again, with the nice, clean compressor and extra power the advantage to goes to ICOM.

Both ICOM and Yaesu, of course, provide the capability of locking uplink and downlink VFOs together for satellite tuning, either for inverting or non-inverting transponders. However, it appears that Yaesu's engineers have a better understanding of how Doppler shift works than the designers at ICOM. The FT-847 provides a small *sub tune* knob that allows the uplink to be tweaked at any time, making the operation practically intuitive. ICOM allows the RIT knob to be programmed in the menus as a separate subband tuning control — but guess what — the function does not work in the satellite mode! Instead, the operator needs to press a button on the panel to unlock the uplink from the downlink VFO and make an adjustment with the main tuning knob, then push the button once again to re-establish the lock. While the Yaesu system is certainly superior, I was able to get the hang of the ICOM buttons in a couple of passes. But it still would be nice to be able to make the adjustment without all of the button pushing. Yaesu clearly has the more functional design.

On the backside of the radios, both companies employ mini-DIN connectors for connection to a packet TNC. While these connectors are inconveniently small to work with, they are probably the price we pay for smaller radios. ICOM has two, one for the Main band and another for the Sub-band. When I wired my TNC into these, I was dismayed to discover that the data stream was cut off abruptly whenever the rig was put into satellite mode for full duplex operation. My questions about this also perplexed ICOM tech support, but after some time and experimentation they were able to tell me that the two connectors are swapped in satellite mode — Main becomes uplink and Sub becomes downlink. This necessitates spitting the wiring between both, and probably adding an outboard switch box between the rig and TNC. Yaesu's design is, again, more practical

Yaesu provides a second mini-DIN as a "STBY" jack, and thoughtfully provides separate keying lines for each band of operation. This makes setting up power amps or switching for things like pre-amps or converters very simple. ICOM, unfortunately, doesn't seem to understand how outboard accessories work. They provide a single standard DIN accessory socket with a single keying line. In the set menus, ICOM provides for the microprocessor to be programmed concerning which bands will key this accessory line when transmitting. If one uses ICOM preamps, which are powered through the coax, and makes no use of other amplifiers of converters, the system won't be problematic. But if one wishes to set up a bypass relay to avoid frying a 2.4 GHz down converter, for example, while at the same time trying to arrange keying for an external power amplifier brick for 1.2 GHz, it's going to require some fancy engineering. Advantage: Yaesu.

While ICOM clearly did not do their homework on accessory keying, neither company wins any prizes for making it easy to use outboard converters or transverters. Adding tranverter or converter connectors is something ICOM routinely has done on HF rigs for decades, but they don't seem to understand the even greater need for these on a VHF/UHF radio, despite the growing interest in microwave bands among both satellite and terrestrial operators. Yaesu has also missed the boat in this regard, and though mods for adding separate receive converter jacks to the FT-847 are available on many web sites, these really ought to be coming from the factory.

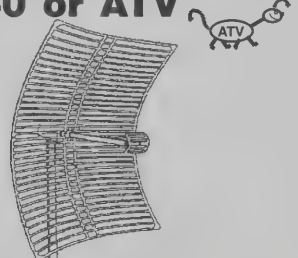
Bottom line — Although it's a pretty close toss up, I've decided to keep the IC-910H. Partly because of my biases in favor of using my various ICOM accessories, but mostly because of stronger transmit and receiver performance and the possibility of adding 1.2 GHz, I'm going to hold my nose concerning some of the design quirks that make Doppler adjustments more awkward, and try to figure out a way around the accessory keying problems.

The FT-847 has definitely earned my respect as a box that provides an extraordinary range of capabilities for the money, but Yaesu needs to do a better job on the receiver if it is going to compete with the *ears* ICOM has built into the '910. Also, Yaesu needs to get back to the open architecture concept, that ICOM has now co-opted, and produce a radio that allows for 1.2 and possibly 2.4 GHz modules.

ICOM, for its part, needs to sit down with some satellite operators and really listen to what we do on the birds, instead of dismissing us as an esoteric group of freaks. If they are going to sell radios advertised as satellite rigs, they really need to get some technical folks on board who understand satellite operation. While Yaesu has done a better job of listening to its customers in this regard, both companies need to do a better job of providing the kinds of connectors on the back of the radio that will allow the convenient addition of accessories, such as amps, preamps, converters, and transverters.

Neither company has perfectly managed the compromises involved in designing a radio for both a general amateur market and for satellite operation. Until they do, both of these radios provide a good foundation for a satellite station, but neither is a turnkey system. Whichever radio you buy, be prepared to do some engineering to overcome the difficulties of connecting it to the real world, and some traveling up the steep learning curve to learn how to use its features. ■

2.4 GHz Antenna for AO-40 or ATV



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AMSAT Journal Telemetry

The Elmer Award Available

Bruce Paige, KK5DO invites all satellite operators to obtain the *Elmer Award*, a new satellite award is now available. This award has three levels, Beginner, Intermediate and Expert and award qualifications are:

Beginner Level
- Work 1 School Club Station
- Work 4 YL Operators
- Work 4 Young Operators (16 and younger)
- Work 10 Operators that have had their license for less than two years at the time of contact

Intermediate Level (includes contacts from Beginner Level)
- Work 2 School Club Stations
- Work 8 YL Operators
- Work 8 Young Operators (16 and younger)
- Work 15 Operators that have had their license for less than 2 years at the time of contact
- Work 2 Operators as their first satellite contact ever (not just on a particular satellite)

Expert Level (includes contacts from Intermediate Levels)
- Work 3 School Club Stations
- Work 12 YL Operators
- Work 15 Young Operators (16 and younger)
- Work 25 Operators that have had their license for less than two years at the time of contact
- Work 4 Operators as their first satellite contact ever (not just on a particular satellite)

Any Amateur Radio satellite may be used for these contacts but contacts must be made by voice or CW. No packet contacts allowed. Contacts with the ISS, Space Shuttle, or any other manned spacecraft are not to be used for this award. Contacts must be made on or after 01 November 2001.

Call signs may be used only once. Therefore, if a call sign fits multiple categories, it is your choice as to which category you claim it for (i.e., Mahana, W5BTS, could be claimed for YL op, Young Op and Op licensed less than two years). School Club call signs count only towards the School Club category.

No QSL cards are required, however, random checks with the operators listed will be performed.

To submit for the award send a list in date/time order with the following information: Date of Contact; Time of Contact; Satellite; and Category to the AMSAT Awards Manager, KK5DO.

Sample

Call Sign	Date	UTC	Satellite	Category
ZZ2ZZ	05 Nov 2001	0300z	UO-14	YL
ZZ1ZZ	06 Nov 2001	0415z	UO-14	YL
ZZ1ZY	06 Nov 2001	0425z	AO-10	Teen
ZZ1ZX	07 Nov 2001	0530z	AO-10	First
ZZ3ZX	07 Nov 2001	0530z	AO-10	New
ZZ4AA	08 Nov 2001	0400z	UO-14	School

A certificate is available for $3.50 for AMSAT members and $5 for non-AMSAT members. Two units of postage are required for return of your certificate. A nice wood plaque for Expert Level is available for $25.

Letters from Stacey Mills, W4SM and Peter Guelzow, DB2OS

From Stacey Mills, W4SM: 10 July 200: I'd like to try to answer a few questions and clear up some misconceptions made in comments on the AMSAT-BB about the AO-40 ArcJet out-gassing.

1. **Was the old orbit stable?** Yes it was. I did the orbital integration and it *was* stable, at least in the sense of not suffering re-entry or meltdown. However, as we all know, perigee was very low. In fact in some simulations, it was as low as 160 km. There was considerable drag at perigee, which continuously changed the mean motion and probably contributed to the perturbation in ALON (the mystery effect). The Keplerian elements on the spacecraft had to be frequently updated. The rapidity of the perigee flyby made magnetorquing very tricky and required a lot of time to determine attitude. To improve these things we wanted to raise perigee height. That doesn't mean the old orbit wasn't stable, but it certainly wasn't optimal, and it was close enough at perigee in June to be frankly scary.

2. **Was the command software controlling the arcjet faulty?** No, it most certainly was not. I wrote it and the rest of the command team checked it. It functioned perfectly in all the simulations. There is not a shred of telemetry evidence to suggest a software error.

3. **Are we out of ammonia?** As far as we can tell, yes.

4. **Where did it go?** We don't have all the answers, and hence we have not yet posted a full report. It appears that the TMFC (thermal mass flow controller) failed, passing far more gas than it should have. There was *no indication* of this in the telemetry. Spin rate changes and telemetered flow rate, etc., all appeared in a safe range. The software properly set the TMFC to 50% flow rate. This should have been ~25-30 mg/s of flow. Even fully open, the TMFC should not have exhausted more than 100 mg/s, which should have left ~60% of the ammonia unused, even after 58 hours of run time. The telemetry suggests that the gas ran out after approximately 1575 minutes (26.25 hrs.). If the tanks were full, that's 560 mg/s, far in excess of what the TMFC should have allowed. Again, we're still looking at this for better answers. As has been noted, we really only needed about half of the fuel to get to the orbit we're in, so it is quite possible that there was also a slow leak in the ammonia tanks such that we started with only approximately half of the fuel. If this were the case, then the flow would have been ~280 mg/s, still almost three times nominal maximum flow rate. Looked at another way, the new and old orbits indicate an apogee velocity change of 40 m/s. Accelerating a 500 kg mass through 1575 minutes indicates a force (thrust) of 0.213 N. That's over twice as high as would have been achieved if the motor were used in a proper powered ArcJet burn. Unlike the helium tank, the ammonia tanks have a liquid/gas interface in equilibrium, so the pressure in the tanks is not proportional to the amount of liquid they contain. Pressure is a function only of temperature as long as liquid ammonia is present. Thus, there was no way to tell how much *fuel* we had. If we did have a slow leak it is very fortunate we did not wait any longer to use the remaining fuel.

5. **Why wasn't the orbit checked after the first test outgassing?** Because of changing solar angle, the mystery effect and precession, moving ALON, as well as the rapidly decreasing perigee height in late June due to solar/lunar forces (which might make attitude even harder to maintain), it was important to complete the maneuver as soon as possible while conditions were right and then begin the move back to 0/0. A nominal single test burn should have produced so little change in perigee height as to be hard to detect against background *noise*. In

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addition, waiting for good Keplerian elements following the test could have required more than a week (current case in point). There was nothing in the test telemetry to suggest a problem, so we proceeded with the full maneuver. From a pragmatic point of view it was always clear that any radical departure from expected would make it highly unlikely that we would be able to maintain a stable, low-volume gas flow as needed for a powered ArcJet burn, so loss of extra ammonia would likely have little effect on the powered ArcJet use.

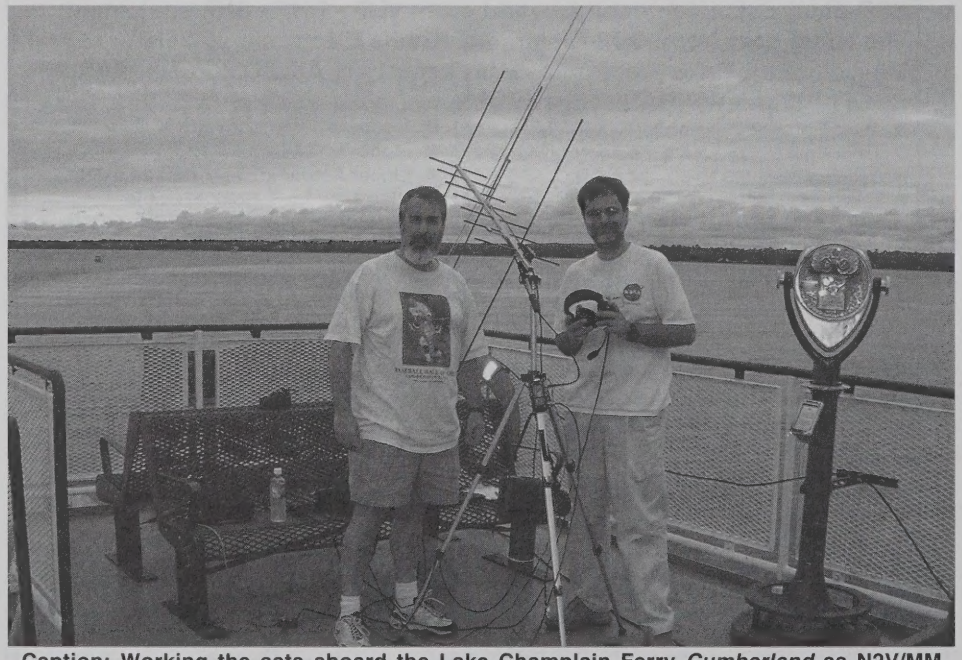
6. **Do the command stations know what they're doing?** We like to think so. There is *absolutely no evidence* that the ammonia problem was due to a command error. I cannot state that any clearer. Please bear in mind that we all take this task extremely seriously, and we spend a *huge* amount of time on it. Just getting AO-40 into the 270/0 position for the out-gassing took several weeks of effort and calculation. When there is a problem, the amount of time required goes up exponentially. The first requirement is to maintain the integrity of the spacecraft, then to gather critical information while it is still available, then to analyze the information, and then to report the findings. I freely admit that my first thought when there's a problem is *not* to post a message to the amsat-bb. This is not because we want a *cover-up* although I have been personally accused of this at least once in quite objectionable terms. The reality is that we are busy trying to figure out if we still have a safe spacecraft, and then determine what's going on. When we are sure that we have the best possible information, we fully report our findings.

7. What's going to break next? The short answer is that we don't know. I sincerely hope that nothing else malfunctions for a long, long time, but this is after all, rocket science. Nothing is guaranteed. However, there has been the suggestion that the command stations are rushing to test things without considering failure scenarios. Nothing could be further from the truth. Weeks of discussion were devoted to the ArcJet and possible failure modes. These discussions involved the designers and builders of the ArcJet, the management team, etc. Out of these discussions came the decision to *cold outgas* before trying hot out-gassing, and to orient to raise perigee, since a faulty or stuck valve in this orientation would not destroy the orbit. Consider that if we had been oriented differently we could be at -350 km rather than +850 km perigee height!!

The momentum wheels have not yet been tested. Rest assured that when they are, it will be after lengthy discussions regarding failure possibilities, recovery modes, etc. I do not regard this as a particularly risky test, unlike the ArcJet, but it will still be approached very, very carefully. Finally, the decision to deploy the solar panels will be much more involved. This is a *no return* event and will in all likelihood be a considerable time in the future after prolonged demonstration that the momentum wheels are fully functional and that 3-axis control software is up to the task. If there are *any* problems in this regard, we will stay in spin mode!!! Our primary goal at the moment is to get AO-40 back into an orientation where the transponders can be operational and RUDAK testing can be completed.

8. **And finally:** I hope this clears up at least a few points. I know this is a frustrating issue for the users and supporters, but believe me, it's also very frustrating for the command stations. A lot of software written and tested for the *hot* ArcJet, will now never be used. And my frustration is totally insignificant next to that of the wonderful folks who put years of effort into building the ArcJet, and now will not see it function. I must admit that my disappointment is compounded by some of the comments that appear on the amsat-bb questioning the abilities and motives of the command stations. I try not to take these personally, and I realize that you would all like answers. So would we. We do have a very stable orbit and we are moving back towards 0/0 to make AO-40 available for your use. All in all, it could be a lot worse, a whole lot worse. I'd like to thank all of you who have posted supportive comments on the amsat-bb. I'd even like to thank those who have questioned our abilities. At least your comments show that you're interested. We can withstand your critical scrutiny! If we can't we need a new hobby.

Peter Guelzow, DB2OS: 11 July 2001: I should add a few points to Stacey's excellent summary.



Caption: Working the sats aboard the Lake Champlain Ferry *Cumberland* as N2V/MM are Ferry Boat Captain Mark Duba, W1MAD (left) and Mike Sequin, N1JEZ (right).

4. **Where did it go?** We don't have all the answers, and hence we have not yet posted a full report. There are a few things to remember...We got the ATOS (Arcjet Thruster on OSCAR Satellite) for free and we designed/built the power supply for it in return.

We haven't yet posted a full report, because those who built and designed the ATOS should have a chance to review all the facts we could provide and probably make an official conclusion out of it. It's their business, not ours. They are currently looking in every possible direction, doing a failure tree analysis and it would be unfair to post something based on speculation, which is than published everywhere.

We only know that everything was done on our side to make it a success.

We were lucky to get the perigee raised enough, so that we don't have to worry about the low perigee. Yes, we were told that it was safe, but who knows... now we can feel **much** better. We were also told that AO-13's orbit would be safe before we burned all the fuel.

What did the users miss? Nothing. There would not have been enough ammonia for a significant change in inclination. Perhaps we could have made 10-20° in inclination change, but then we would periodically have bad coverage due to the processing orbit, with the apogee being over the wrong hemisphere (from either point of view) for some time. Instead we could have reduced the apogee height making it a 16h orbit, but this also makes not such a big deal at the low inclination and the path loss also does not really get much better. So what?

Indeed, it is very disappointing that we could not demonstrate the ArcJet burning *hot*. On the other hand, ATOS has never flown before and it is highly experimental and rocket science. At least we learned that this type of TFMC (mass flow controller) is not flight worthy. This is something in which could not have been simulated on the ground.

To be honest, we were not even sure if the Arcjet motor was still there. You all have heard the speculation that the bottom plate was blown away. Obviously at least the motor was still there at the right position and mounting angle.

7. **What's going to break next?** No risk, no fun?

If everything would be so easy, than there would be no role for AMSAT in space anymore.

There is no other way except trying. But be assured that everything and every possible failure mode is discussed in detail, before any decision is made. We don't use crystal balls. In fact, we were told that the failure mode of the TFMC is that it gets shut and not open wide.

We will have enough time to check out the momentum wheels. And to be honest again, I would be surprised if they all work OK after the possible destruction in the inner core of the spacecraft. But we have no other choice, we must try! Also risk is predictable. If everything goes well, we will proof test the 3-axis control for a **long** time before we will deploy the solar panels (if at all).

8. **And finally** We can withstand your critical scrutiny! If we can't we need a new hobby. Otherwise I wouldn't be here anymore, since I have spent most of my life for it since AO-10.

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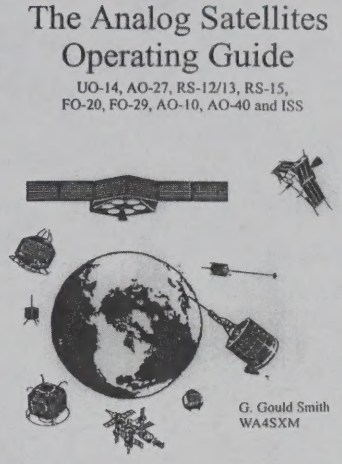

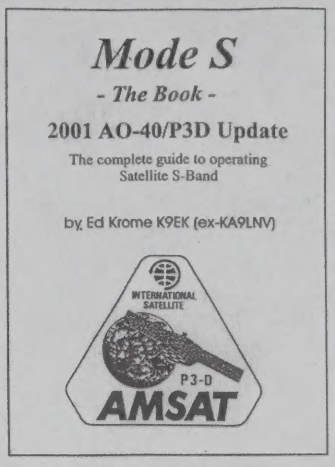

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